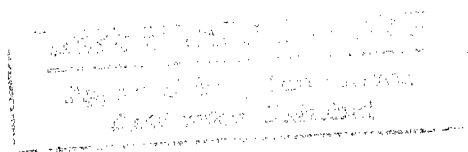


**RAND**

*Application of F-117  
Acquisition Strategy to  
Other Programs in the New  
Acquisition Environment*

*Giles K. Smith, Hyman L. Shulman,  
Robert S. Leonard*

**50<sup>th</sup>**  
**Project AIR FORCE**  
1946-1996



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## PREFACE

It is frequently argued that Special Access Programs (SAPs) are more effectively and efficiently managed than their counterparts conducted in a more open environment. The F-117 program offers an unusual opportunity to test, at least in a limited way, the hypothesis that SAPs have certain characteristics that could be applied beneficially to other programs. Developed and produced as a covert program under strict access controls, many details of the F-117 program have since become available to a wider audience, thus permitting at least a preliminary analysis of some of the program acquisition procedures.

Two related but separate issues are examined in this report. First, how was the program managed, and how did those management strategies affect the program outcomes? Second, if some beneficial strategies can be identified, to what extent might they be applied to a wider range of acquisition programs, and especially to programs that might reflect the more austere funding environment anticipated for the future? Results of the analysis should be useful in formulating acquisition policies for the next generation of weapons acquisition programs.

This work has been performed under the Acquisition Project in the Resource Management and Systems Acquisition Program of Project AIR FORCE. It will be of interest to U.S. Air Force and other military personnel, analysts, policymakers, operational commanders, and students who are concerned with the efficient use of military resources, particularly in the context of acquisition.

Project AIR FORCE is celebrating 50 years of service to the United States Air Force in 1996. Project AIR FORCE began in March 1946 as Project RAND at Douglas Aircraft Company, under contract to the Army Air Forces. Two years later, the project's contract and personnel were separated from Douglas to form a new, private nonprofit institution to improve public policy through research and analysis for the public welfare and security of the United States--the foundation of what is known today as RAND.



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## SUMMARY

### BACKGROUND

It is frequently argued that Special Access Programs (SAPs) are more effectively and efficiently managed than their counterparts conducted in a more open environment. Unfortunately, such programs usually remain under tight security control, making it impossible to rigorously test the accuracy of the claims or to systematically identify and apply strategies and attributes to a wider variety of acquisition programs.

The F-117 program offers an unusual opportunity to test, at least in a limited way, the hypothesis that SAPs have certain characteristics that could be applied beneficially to other programs. Developed and produced under strict access controls, many details of the F-117 program have since become available to a wider audience. Furthermore, the program has three other characteristics that make it an attractive subject for such analysis:

- The F-117 weapon system is generally viewed in favorable terms, based in part on its dramatic performance in the Persian Gulf war.
- Except for the special "stealth" performance feature, the F-117 program shares enough features with other airplane programs to permit useful comparisons of inputs and outputs.
- The Air Force direct management staff required to oversee the program was about one tenth that of a typical fighter aircraft acquisition program. In an era when considerable emphasis is being placed on reducing the size of government, any organization or process that allows the government to manage with far fewer people deserves careful attention.

Our analysis of this program focused on three related goals: (1) to describe the actual procedures used in the acquisition process; (2) to define the program outcomes and, to the extent possible, relate those to the acquisition procedures; and (3) to identify any apparently advantageous

management objectives, procedures, and operating concepts that might be applied to a broader range of programs.

## **ACQUISITION STRATEGY AND PROCESS**

### **Operating Principles and Procedures**

A central aspect of the F-117 acquisition program was its exceptional flexibility and responsiveness in decisionmaking. This characteristic was aided by several important features of the program structure.

- The CPFF (cost-plus-fixed-fee) contract used to fund the development phase provided an overall institutional framework wherein decisions could be implemented with a minimum of fuss and delay.
- The system specifications were expressed in the form of contract goals rather than hard requirements. This featured allowed managers the flexibility of tailoring design decisions to overall program goals instead of having to satisfy a large number of predetermined measures of contract performance.
- Effort was narrowly focused on achieving a true LO (low observable) airplane and doing it quickly and in great secrecy.
- An unusual degree of professional respect and rapport existed between the Air Force managers and the industry managers, which led to good communications and the prompt resolution of issues.
- The Air Force program office staff was exceptionally small, about one-tenth that of a typical combat aircraft program office. In part, this was made possible because of the "silver bullet" program concept. A very small production run was anticipated, followed by operation in a special environment, thus substantially reducing the emphasis on extensive design maturation before the start of production. Also, every member of the staff was empowered to a high degree. Staff members were handpicked for their particular kind and level of expertise, and they were encouraged to act independently and to minimize administrative coordination unless they deemed it necessary.

### **External Environment**

The SPO (System Program Office) procedures and performance outlined above could not have been achieved without certain special enabling features of the environment in which they operated:

- The program was covert, which strictly limited the number of people who might have an opportunity to meddle in program management and shielded the program from the critical scrutiny of public and media who do not understand the dynamics of complicated, high-technology development programs.
- The program received strong institutional support from the small community of senior officials who had management responsibility, and that support did not waver throughout the development and procurement phases. Furthermore, those senior officials had the authority to issue enabling directives as necessary. Thus, the management communications from the SPO to higher headquarters was fast and efficient.
- No major changes were made in performance requirements or other program specifications after start of development, except for increasing the total quantity of aircraft produced. The consequent degree of program stability relieved the contractor and Air Force (AF) program office staffs from the burden of system redesign and program restructuring that is typical in conventional programs.
- The F-117 was never in the main stream of AF combat aircraft programs. Only 20 operational aircraft were expected to be produced, and those would operate in ways not even envisioned by standard Air Force doctrine. While the program sponsors certainly believed the F-117 would provide a new and important combat capability, the system was never expected to play a major role in AF force structure.

### **PROGRAM OUTCOMES AND LINKAGES WITH ACQUISITION PROCESS**

In most regards, the F-117 program outcomes appear representative of contemporary weapons acquisition programs. Key performance goals were

achieved, as they are in most military aircraft development programs. Actual development schedule was comparable with that of contemporary programs. The total acquisition cost of the F-117 program was roughly comparable with the costs of contemporary fighter aircraft systems, after adjusting for production quantity and other major program and design differences.

Two special aspects of program outcomes deserve special attention. One is that while conforming to typical cost and schedule outcomes, the F-117 developers introduced a novel configuration that incorporated a radical new technology, LO, and an entirely new operational concept through the successful combination of LO and precision weapon delivery. If there is a major cost penalty associated with LO performance, as believed by many and as suggested by fragmentary studies, and a further cost penalty (10 percent has been suggested) resulting from exceptional security restrictions, then these considerations suggest that the F-117 costs were somewhat less than might have been expected in a conventionally organized and managed program.

The second special aspect of program outcomes is that the relatively low level of attention devoted to R&M (reliability and maintainability) considerations during F-117 development almost certainly reduced the cost, and possibly the duration, of the EMD (engineering and manufacturing development) phase, but the extent of those reductions cannot be quantified. Furthermore, it should be noted that those same practices led to increased costs of operational support and probably caused some delay in achieving true IOC (initial operational capability).

Other specific linkages between acquisition strategy and program outcomes cannot be made because too many elements of this program were unusual, and we cannot confidently separate their individual effects.

#### **CAN F-117 MANAGEMENT STRATEGIES BE MORE WIDELY APPLIED?**

From the complex interplay of cause and effect that we have observed in this program, we can make one unambiguous conclusion: if a special environment similar to that which existed in the F-117 program can be achieved, then it is clearly possible to successfully manage a major acquisition program with staffs very much smaller than are common in

"typical" acquisition programs.<sup>1</sup> However, a substantial set of "special circumstances" is a necessary and enabling condition. At least four elements of such an environment seem critically important:

- Strong and sustained support for the program, thus enabling a high degree of program stability, together with freedom from having to constantly defend and protect the program from critics;
- A willingness to delegate decision authority to relatively low levels of the organization, to enable response to problems and issues that is both rapid and based on a thorough understanding of the program;
- Some tolerance for risks and uncertainty about detailed program outcomes; and
- Ability to staff the program office with people fully qualified to assume the responsibilities vested in them.

It seems unlikely that such an environment can be created for a wide range of acquisition programs, simply because of the constraints built in to our form of government. Furthermore, we would not advocate that the F-117 acquisition strategy and management practices be applied in every new program. Each program is different, and we strongly believe that the acquisition strategy and management approach needs to be tailored to the circumstances of each individual program. One size does not fit all. However, at least two elements of management strategy almost certainly could and should be more widely applied:

- Delegate more decision authority to the program office level, with a concomitant reduction in detailed, documented oversight by higher HQ.
- Contractually "require" only a very few key performance requirements and establish reasonable goals for the remainder. Additionally, a clear set of program priorities must be

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<sup>1</sup>This would be true even if more attention were given to R&M issues than was evident in the F-117 program.



established to guide designers and managers when making design decisions.

A common thread running through these initiatives is that to implement them requires a substantial level of mutual trust and professional respect among the various government agencies involved in the acquisition and between the government staff and the contractor(s). A lack of such trust and respect is the basis for many of the process controls that were specifically waived in the F-117 program. It is promising to note that many of the acquisition reform initiatives now being sponsored by senior Department of Defense (DoD) and service acquisition officials appear to encourage trust, respect, and even the use of common sense among acquisition managers, but conclusive results of such reforms have not yet been widely observed.

#### **ACKNOWLEDGMENTS**

Any study that involves the collection of widespread data requires the support of many people. We want to acknowledge our special appreciation to Colonel George Zielsdorff and Lieutenant Colonel Glen Kuller for their help in making files available at the Aeronautical Systems Center and to Mr. Jerry Potter for similar assistance at the Sacramento Air Logistics Center. Without their active cooperation, we could not have accumulated the information necessary to describe and analyze the F-117 program.



# ACRONYMS AND ABBREVIATIONS

AF	United States Air Force
ALC	Air Logistics Center
ARPA	Advanced Research Projects Agency
ASC	Aeronautical Systems Center
CDRL	Contract document requirements list
CPFF	Cost-plus-fixed-fee
CU	Configuration upgrade
CY	Calendar year
DoD	Department of Defense
DODD	Department of Defense Directive
EMD	Engineering and manufacturing development
FC	Fire control
FFP	Firm fixed price
FMS	Foreign military sales
FPI	Fixed price incentive
FPIF	Fixed price incentive fee
FY	Fiscal year
GFE	Government furnished equipment
HQ	Headquarters
HUD	Head-up display
INS	Inertial navigation system
IOC	Initial operational capability
IR	Infrared
IRADS	Infrared Acquisition and Detection System
LO	Low observable
LWF	Light-weight fighter
MilSpecs	Military specifications
MilStd	Military standards
O&S	Operation and support
R&D	Research and development
R&M	Reliability and maintainability
SAPs	Special access programs
SAR	Selected Acquisition Reports
SPO	System Program Office
USAF	United States Air Force
WUC	Work unit code

## I. INTRODUCTION

Over the past few years, there has been renewed emphasis on reforming and improving the weapons acquisition process. In part, such efforts simply reflect the latest in a continuing series of attempts to improve the efficiency and effectiveness of the acquisition process. But recent reform efforts are also being stimulated by certain new constraints on weapons acquisition, reflecting the dramatic reductions in the role that national defense plays in our overall national strategy and the consequent budget allocations: (1) sharply reduced military force size, with the attendant reductions in weapon production quantities and rates; (2) the changing relationship between industry and government as the defense-unique elements of industry shrink in size and capacity; and (3) the broad mandates to shrink the size of government staffs and infrastructure in general.

One "reform" that is frequently advocated is to apply at least some of the acquisition strategies used in Special Access Programs (SAPs) to a wider range of acquisition programs. Such advocacy is generally founded on the belief that SAPs are more efficiently managed and executed than are typical "white world" programs.<sup>1</sup> However, not much factual information has been available to support such claims, simply because the details of SAP management and outcomes have typically remained highly classified. However, the issue remains tantalizing. If special "streamlined" program organization and management methods could be shown to have been particularly effective in some programs, then we should make a special effort to understand how, and to what extent those practices might be more widely applied in future acquisition programs.<sup>2</sup>

The F-117 program offers an unusual opportunity to test, at least in a limited way, the hypothesis that SAPs have certain acquisition strategy and program characteristics that could be applied beneficially to other programs. Developed and produced under strict access controls, many details of the F-117 program have since become available to a wider

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<sup>1</sup>Programs in which most of the broad programmatic information is in the public domain.

<sup>2</sup>See *Defense Management Review Report on Air Force Special Access Programs*, January 1990, for a more general discussion of the topic.

audience. Furthermore, the program has some other characteristics that make it seem particularly relevant to the new acquisition environment outlined above::

- It was produced at low rates, with a small total production quantity.
- It started as a very specialized "silver bullet" program and transitioned to an enduring element of the regular force structure.
- The Air Force direct management staff required to oversee the program was about one-tenth that of a typical fighter aircraft acquisition program.

Two other aspects of the F-117 acquisition program make it a particularly attractive candidate for analysis. The first is that, except for the special "stealth" performance feature, the F-117 program shares enough features with other airplane programs to permit useful comparisons of inputs and outputs. The second is that the F-117 weapon system is generally viewed in favorable terms, based in part on its dramatic performance in the Persian Gulf war. To students and critics of the weapons acquisition process, this is an important distinction. Rather than the usual context of trying to learn how to avoid repetition of some undesirable outcomes, here we are offered a successful program from which to learn some positive lessons.

The issue of System Program Office (SPO) size is one of the central issues in our analysis of streamlined management practices. In an era when considerable emphasis is being placed on reducing the size of government, any organization or process that allows the government to manage with far fewer people deserves careful attention.

A comparison of SPO staff size in the F-117 program with SPOs in some other programs is shown in Figure 1. This kind of comparison must be viewed with some caution because the SPOs for the three "white world" systems are depicted as they were in early 1994, (because of difficulty in finding historical data on those or similar programs) whereas the F-117 is depicted as it was during the mid-1980s. In each case the data include

only United States Air Force (USAF) military and civilian personnel (excluding FMS (foreign military sales) personnel) and only people located at the product centers (excluding people at the Air Logistic Centers (ALCs)). Comparison with the C-17 and F-22 appear valid because both of those programs are in EMD or early production, as was the F-117 at the time the SPO staff size was estimated to be about three dozen people. Comparison with the F-16 might be suspect because in 1994, procurement for the USAF was nearing completion and the management effort was focused on configuration upgrades and production for foreign customers. However, aircraft system SPOs typically have staffs of 300 to 400 people, and the F-117 SPO staff was obviously much smaller. We wish to understand the enabling factors and the consequences related to that small SPO staff size.

Another valuable characteristic of the F-117 as the subject of analysis could not have been fully perceived prior to the study: the degree to which the F-117 program was structured and managed in ways quite different from the standard practices as outlined in DoD and Air Force directives.<sup>3</sup> Here we must make a sharp distinction between broad

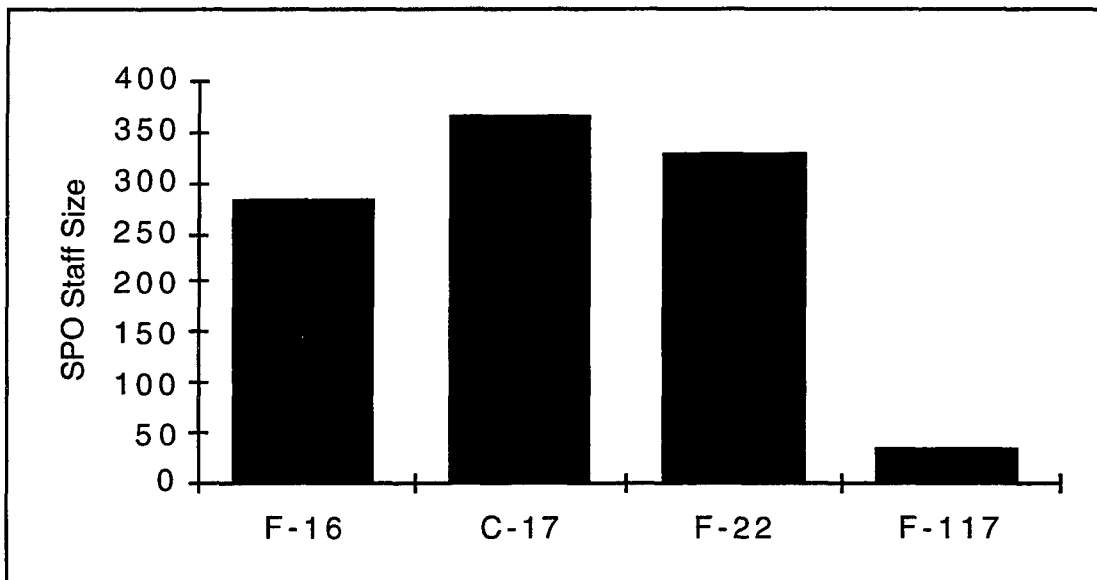


Figure 1--SPO Size Comparison

<sup>3</sup>We recognize that the "standard" procedures are currently undergoing intensive review and modification. Throughout this report we will refer to the standard procedures as they existed during the 1991-1994 time period and will make no attempt to make comparisons against the moving target of reform efforts.

acquisition *policy* and detailed *administrative practices and procedures*. In terms of broad policy, the F-117 program reflected the judgment of highly experienced and capable Air Force acquisition managers and functional specialists and was not inconsistent with underlying principles reflected in formal policy statements. It was in the overlay of administrative procedures that the F-117 program differed dramatically from conventional program. For more than two centuries, our government has wrestled with the problem of how to buy the materiel needed by our combat forces, and the practices have fluctuated between wide extremes.<sup>4</sup> During times of crisis the procedures have been quite flexible, with considerable authority delegated to field staffs. Invariably, someone would perceive some of the actions taken during those times as involving fraud, waste, or abuse, and rigorous controls would be instituted to prevent their recurrence. Despite the exigencies of the cold war, the past several decades have been characterized by ever-tightening administrative controls. However, the F-117 management structure incorporates a high degree of local management autonomy, combined with minimal oversight and documentation. Thus, the program provides an exceptional degree of contrast with many of the administrative practices that have come to be accepted as standard over the past two or three decades.

#### **ANALYSIS OBJECTIVES AND APPROACH**

The objectives of this study were:

- To describe the special management strategies employed in the F-117 program and to identify the actual program outcomes;
- To identify the degree to which those special management strategies appear to have led to outcomes more or less desirable than were typical of comparable programs managed under conventional practices; and
- To draw overall conclusions about the desirability and practicality of applying the management practices used in the

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<sup>4</sup>A good review may be found in James F. Nagle, *A History of Government Contracting*, The George Washington University, 1992.



F-117 program to a broader range of future aircraft acquisition programs.

The overall analysis consisted of three tasks. The first was to prepare a limited case history of the F-117 program, focusing on the acquisition strategy and management procedures, the evolution of the program, and the final results in terms of cost, schedule, and system performance. The information reported here covered only the acquisition phase, starting in 1978 with the beginning of EMD and ending with delivery in 1990 of the last aircraft produced. While far from being a complete case history, because many aspects of the program are not dealt with, we believe that enough information was obtained to support the overall study goals.<sup>5</sup>

In the second step, the F-117 program was compared with "comparable" programs (i.e., other fighter programs of recent vintage, namely the F-14, F-15, F-16, and F-18). We sought to identify any ways in which the F-117 program differed substantially from those other programs and to determine the extent to which differences in acquisition strategy could be linked with differences in program outcomes.

The third step was to examine those results and draw conclusions. That phase of the analysis also included a review of aspects of the "external environment," such as oversight review and program stability, that seemed relevant to the management performance in the F-117 program.

#### **DATA SOURCES AND ANALYSIS LIMITATIONS**

The information contained in this report is largely based on original Air Force program documents, including Program Management Directives, contracts, financial records, and similar sources that were reviewed at the System Program Offices at the Air Force Aeronautical Systems Center (ASC) and the Sacramento Air Logistics Center. Those data were augmented by interviews with several members of the management and technical staffs of the F-117 program offices during the period under review.

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<sup>5</sup>In the categorization suggested by Robert Yin in *Case Study Research: Design and Methods*, 2nd ed., Thousand Oaks, Calif.: Sage Publications, 1994, this would be defined as a single-case design employing a single unit of analysis.

Despite the authors' extensive access to program documents and personnel, the reader should be alerted to several problems that constrain the scope and quality of the study results. The first is that comparisons of the F-117 program with other acquisition programs depend on an important assumption: that the outcomes of all programs examined in the comparison were logical consequences of the program objectives, the acquisition strategy, and the overall environment within which the programs were conducted. This analysis does not constitute an "evaluation" either of the F-117 or of any of the related programs with which it is compared. Each program is assumed to have performed in a reasonable way, given the program objectives, acquisition methods, the general environment, and other factors. Each new weapon system is unique in many ways, and many different criteria can be applied to each. Trying to decide if a program was "well managed" or "poorly managed" is usually an exercise in futility. Here we simply assume that each program is a logical outcome of the strategies, priorities, and limitations imposed on it. We then try to identify links between program structure and program outcomes.

Another problem, one not typically found in acquisition analysis, is that we cannot guarantee that our description of the F-117 program is sufficiently complete and accurate to support our analysis objectives. It is the nature of Special Access Programs that even if some information is released, other aspects may not be revealed because of continuing security constraints.

Finally, we are dealing with a single sample. We can draw conclusions based on the special acquisition strategies we saw applied to the F-117, but we do not know if the F-117 is representative of the broader class of Special Access Programs, and we make no claims that the results are representative of SAPs in general. This study is, therefore, a contribution to the assessment of SAP management practices, but it is far too limited to stand alone as a definitive assessment.

The issue of sample size is broader than whether the F-117 is representative of SAPs in general. The question exists of whether we have really identified the decisions and events that had primary effect on the program outcomes. Program documents are notoriously deficient in this regard: they tend to record what happened, or what was *intended* to happen,

but almost never say why those particular procedures were applied or those outcomes desired or achieved. Yet, without some understanding of the implementation process and decision environment, including an appreciation of the incentives and constraints that influenced the participants, we are liable to misinterpret some of the information. This problem is particularly acute when dealing with the Special Access environment because it is different from the normal management environment and processes in many ways. Special attention was paid to this problem via extensive interviews with senior executives in the program, but the problem remains troublesome.

All aspects of this analysis must be viewed with these constraints in mind.

#### **REPORT OUTLINE**

A summary description of the F-117 program (task 1 in the above description of analysis objectives and approach) is presented in Section II. Comparisons with comparable programs (task 2) are presented in Section III, and overall conclusions (task 3) are shown in Section IV. An appendix describes our analysis of some issues that arose during examination of F-117 maintenance support records.

## II. F-117 PROGRAM DESCRIPTION

In this section, the F-117 program will be described in terms of its general acquisition strategy, organization, and outcomes (schedule, performance, and cost). This description will provide the reader with the overall context of the program and establish a baseline for the comparison of the F-117 to comparable programs in the following section. This description is not intended to be a complete case history of the F-117 program but is limited to those aspects deemed particularly relevant to issues of acquisition policy and procedure.

### PROGRAM OVERVIEW AND CHRONOLOGY

The F-117 engineering and manufacturing development (EMD)<sup>1</sup> phase was preceded by the "Have Blue" technology demonstrator program. Building on earlier work under the sponsorship of the Advanced Research Projects Agency (ARPA), the Have Blue demonstrator program started in mid-1976 with the objective of demonstrating effectiveness of the design concept in reducing radar and IR (infrared) signatures. Two aircraft were built that successfully demonstrated the design concept during an 18-month flight test program.

To understand the role of the Have Blue aircraft in the overall program, it is important to distinguish between *technology demonstrators* and *prototypes*. The Have Blue aircraft were true technology demonstrators, whose only objective was to demonstrate that an actual flight vehicle (vice a pole-mounted model) could achieve a projected level of signature reduction. The aircraft were sub-scale and were built without regard to any objective but that of flying in a test environment. In the words of one program participant, the aircraft were "barely flyable," and, in fact, both models were destroyed during the test program of only 88 flights. However, enough information was gained to validate the design concept and to convince most skeptics that an operational system could be designed.

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<sup>1</sup>We use this modern terminology throughout the report, rather than the terminology that existed at the time of the F-117 program and that is found in the original documentation.

The subsequent F-117 model was a completely new and different design that utilized the signature reduction strategies demonstrated in Have Blue.<sup>2</sup>

While the Have Blue aircraft were being designed and tested, Lockheed conducted design studies of several different operational configurations, applying the general design concept to different mission applications. In mid-CY78, they submitted a proposal for a subsonic "fighter" (actually an attack aircraft), and full scale development of the F-117 was started in November 1978.

At that time, the program was envisioned as being quite small and very tightly scheduled. The goal was to achieve first flight in 20 months, with first operational delivery just ten months later. Five aircraft were to be built for flight test, followed by 20 operational aircraft at a rate of one per month. As shown in Figure 2, this goal led to a schedule that was highly "concurrent." Long-lead authorization<sup>3</sup> for the first two post-development production contracts (Lots 2 and 3)<sup>4</sup> occurred before first flight, and full funding for Lot 2 was scheduled to occur shortly after first flight.

The actual schedule slipped, with first flight being achieved 31 months after EMD start (a slip of 11 months), and first operational delivery 12 months later (a slip of 13 months). Actuals are shown on Figure 2 by the heavy arrows. At least part of the delay was caused by the need to obtain appropriate security clearances for every member of the design and production teams. Furthermore, the initial goal of 20 months to first flight was extremely ambitious, even in the best environment.<sup>5</sup> This

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<sup>2</sup>The distinction between *technology demonstrator* and *prototype* is important in some of the comparisons made in the following section. The F-16A development, for example, was preceded by a true prototype (YF-16) that contributed substantially to the subsequent EMD phase for the F-16 flight vehicle.

<sup>3</sup>Authorization for the contractor to commit funds to buy items that require a long time (typically, two to three years) from order to delivery.

<sup>4</sup>The five flight vehicles included in the EMD contract were designated as Lot 1.

<sup>5</sup>To put this schedule goal in perspective, first flight was 23 months after go-ahead in the YF-16 prototype program, a design activity with somewhat different technology hurdles and none of the severe security constraints imposed on the F-117 program. In fact, no combat aircraft program in recent history has reached first flight in less than 23 months, even if considerable development work had been completed prior to formal EMD start. For a good review of this issue, see Bruce R. Harman, Lisa M.

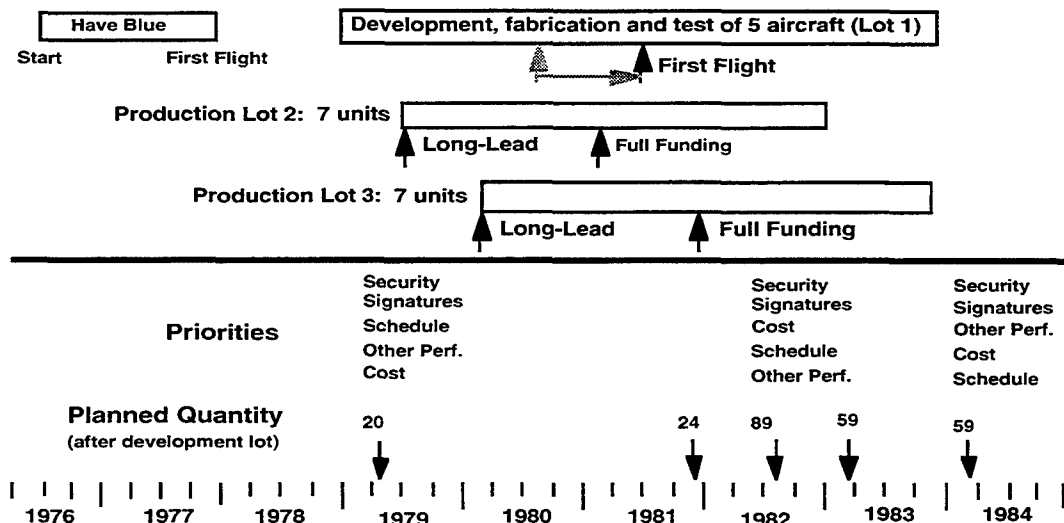


Figure 2--Program Schedule

slippage had the effect of making the program even more concurrent than originally planned, because full funding for Lot 2 was authorized on the original schedule, thus occurring before first flight! This is an indication of the risk level the Air Force was willing to accept in order to accelerate the program.

Throughout development and early production, program priorities and the overall plans for production changed, as shown on the lower half of Figure 2. The initial program focus was on achieving a unique mission capability as quickly as possible. Partly because of the risks perceived by some in achieving the desired technical performance, and partly because of the small size of the envisioned operational force, relatively little emphasis was placed on issues of operability<sup>6</sup> and supportability. The development was performed under a CPFF (cost-plus-fixed-fee) contract, thus allowing some flexibility to match resources to the problem at hand.

Ward, and Paul R. Palmer, *Assessing Acquisition Schedules for Tactical Aircraft*, Alexandria, Va.: Institute for Defense Analyses, IDA Paper P-2105, 1989.

<sup>6</sup>For example, the initial program configuration called for largely manual mission planning methods. A more elaborate automated mission planning system was added later in the program.

As system capabilities were demonstrated and confidence in overall program success grew, the focus shifted from the original one of a very small, highly specialized system to one of a larger force with broader operational goals. A force size as large as 89 aircraft was briefly considered in 1982, and in early 1983, the plan stabilized on the eventual size of 59 operational aircraft. During the same period, the program priorities shifted accordingly. In July 1982, cost was elevated from last to second place, reflecting the larger, planned production run. Later, when basic system performance was assured, attention turned to "other performance" which began to emphasize operability issues. However, there is no evidence that the program was restructured to address the operational supportability issues that inevitably would accompany the larger force size.

The subsequent production program is shown in Figure 3. After the first few units, for which the production pace was defined by the original program plans, the rate was remarkably constant at eight per year for five years, then systematically reduced toward the end of the planned production run.

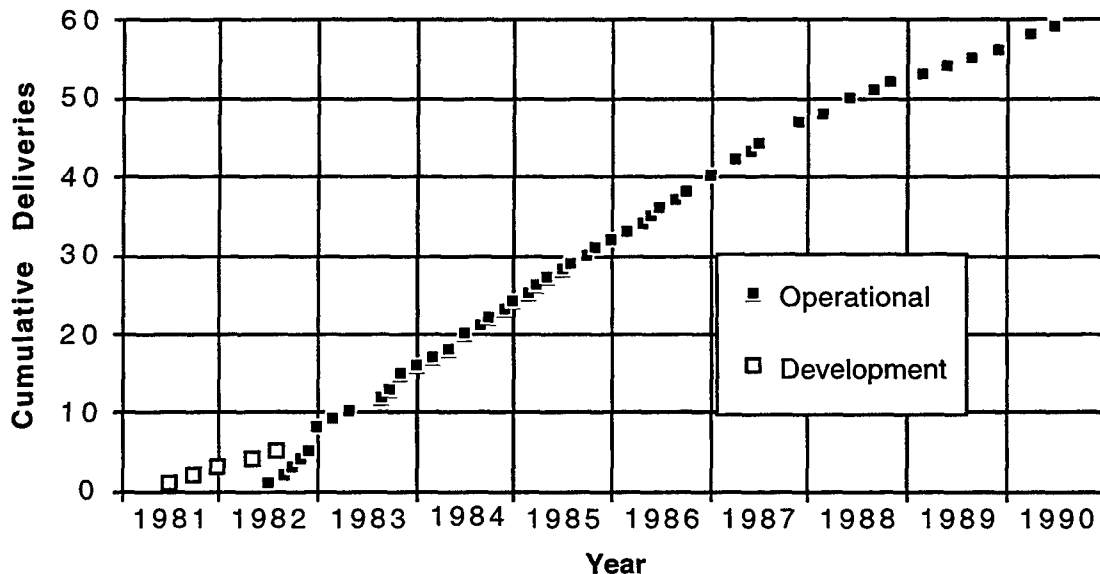


Figure 3--Delivery Schedule

## **DESIGN CONCEPT**

To support the accelerated schedule and to reduce overall program risk, two key decisions were made regarding the design strategy. The first was to base the general configuration on the faceted approach demonstrated in Have Blue. The one deviation from Have Blue was to cant the tail surfaces out, rather than in.

The second design decision was to utilize proven components and subsystems to the greatest degree possible. Thus, the GE F404 engine and the cockpit head-up display were adapted from the ongoing F-18 program, the highly accurate inertial navigation system was adapted from the B-52, many elements of the F-16 flight control system were used, and other existing components were utilized. The only truly new and developmental subsystem was the Infrared Acquisition and Designation System (IRADS) for detecting and designating a target. What kind of overall system performance penalty resulted from this approach is unknown, but it certainly simplified the program and allowed the designers to focus on the system-unique elements of flight vehicle and associated mission equipment.

## **MANAGEMENT ORGANIZATION AND PROCEDURES**

One of the most obvious differences in management organization between the F-117 and other programs was in the size of the Air Force System Program Office (SPO). This organization operated with a total staff of about three dozen people during the height of the EMD phase--a startlingly small staff compared with typical fighter aircraft programs<sup>7</sup>. One of the principle objectives of this study is to understand what permitted such a small SPO staff and how well it performed.

How well any management organization works is critically dependent on hard-to-measure factors such as interpersonal relationships, overall morale, and so on. We will define a few elements that seem especially important to the execution of the program.

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<sup>7</sup>It is exceedingly difficult to determine true staff size or composition during that time period. No records of SPO organization or staffing were found in the program office archives. The problem is further compounded by the fact that the F-117 was one of several programs managed from a "basket" SPO, with at least some of the staff working on more than one project from time to time. The value of "about three dozen" as an equivalent full-time roster for the F-117 is consistent with the recollections of several people in the SPO at that time.



We believe there are two main parts to any discussion of F-117 management. The first deals with the overall management environment that existed outside the program office. Key aspects of that environment included

- Relatively high stability in program objectives and availability of funding. As noted above, the planned production quantity changed, but stabilized before production was very far along, and the changes did not introduce any major inefficiencies in the actual production program. Furthermore, production rate was remarkably stable throughout the life of the program.
- Relatively little management oversight or external intrusion into the program activities.

One key to that environment was the very strict controls placed on program access. In addition to being a Special Access Program, it was also a covert program. The result was that very few people even knew about the program, much less had any information on it or opportunity to affect it. Furthermore, the few people in the oversight administrative structure had the knowledge base, experience, and authority to take appropriate actions based on their own judgment. The key members of the line management organization above the SPO did not need extensive staff support to sustain confidence in the program or to make programmatic decisions when necessary.<sup>8</sup> Thus the overall program environment was such that it seemed possible, as well as desirable, to remove much of the usual panoply of controls and oversight that had grown up around most major acquisition programs.

One important consequence of this highly streamlined management structure was that it made possible some expansion of the envelope of risks that seemed acceptable, especially when those risks promised to yield some

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<sup>8</sup>For this arrangement to work successfully, it is obviously necessary for the key management positions to be filled by highly qualified people, a situation that does not always exist.

returns in the form of accelerated schedule.<sup>9</sup> A small management team, whose members trust each other, can undertake risks that are unacceptable to a larger, more bureaucratic organization.

A second contributor to the environment in which the F-117 program operated was the *scope of the program*. It was originally envisioned as being quite small (only 20 production units were planned) so the outcome was not expected to have a major effect on overall AF force structure, on either its size or composition. Similarly, the capability being sought, while potentially quite valuable, was clearly revolutionary and out of the main stream of Air Force doctrine at that time. The combination of those two factors meant that the program did not need to perform the detailed coordination or to conform to force-wide standards that would have been required of a larger force component.<sup>10</sup>

Given that special external environment, the SPO used a number of special tactics in the direct management of the program. The key elements of those tactics are summarized below.

#### **Contract Structure**

The contract forms that were used provided both the Air Force and the contractor considerable flexibility during the early parts of the program when major risks and uncertainties had to be resolved. An overview of the major contracts is shown in Table 1. The initial development work, extending from the start of the program in late 1978 to the end of formal EMD (estimated to have occurred in mid-1984), was performed under a cost-plus-fixed-fee (CPFF) contract. That seemed appropriate, given the novel design problems that had to be solved. However, as described more fully in the next section, the configuration required considerable development work after the end of formal EMD to achieve the desired level of operability and supportability. That further work was covered under a fixed price

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<sup>9</sup>The operational advantage provided by any technology must be considered short-lived, so the value of a new capability such as stealth is enhanced by early introduction into the operational force.

<sup>10</sup>This "silver bullet" concept, combined with the covert nature of the program, led to problems after the F-117 became operational. The force commanders did not fully appreciate the capabilities of the system because they had not had any opportunity to build confidence in its combat performance through operational exercises; nor did they have confidence that it would be available to them when they needed it.

incentive (FPI) contract. Even that contract was administered with remarkable flexibility. The initial FPI contract was definitized in 1983 but was changed so many times in subsequent years that by 1992, the dollar value had grown to more than three times the original value. The continuing development work was further supported by another contract that covered additional flight testing (not shown in Table 1).

As the configuration was refined through continuing development work, the aircraft already produced were retrofitted with those upgrades in a depot modification program. That is indicated by the Configuration Upgrade entry in Table 1.

Production of operational aircraft was in ten lots. The first five lots (numbered 2 through 6), covering a total of 28 aircraft, were produced under FPI contracts, and each of those lots was completed at a value close to the definitized price. The following five lots, covering the remaining 31 aircraft, were performed under firm fixed-price contracts, which might be expected to be even more stable in total dollar value. However, some of those were modified to cover an expanded scope of work, resulting in an increase in face value that in one case was almost 50 percent greater than the initial definitization. We have little information about the details of either initial pricing or the source of subsequent changes, and these references to cost changes are not intended to be pejorative in any way. We do wish to point out that one needs to be careful in interpreting the "fixed" aspect of these contracts; the work covered in the original work statement might well have been completed under the specified fixed contract, but the contract scope was sometimes expanded to cover

**Table 1**  
**Major Elements of the Acquisition Program**

Activity	Contract Type	Years Covered by Major
		Expenditures
Initial Development	CPFF	1979-1983
Follow-On Development	FPI	1984-1990
Config. Upgrades	Mixed	1984-1990
First 28 Prod. Units	FPI	1980-1984
Next 31 Prod. Units	FFP	1984-1989

considerably more work than originally specified, with the total cost expanded correspondingly.

### **System Specification**

A second key decision on development strategy was to set an absolute minimum number of design and performance specifications as hard requirements, leaving the remainder as goals. This decision provided the designers with considerable freedom when making the inevitable compromises and choices necessary in a system design. That freedom, coupled with a tight decisionmaking management structure (see below) almost certainly saved time and cost during development. The system specification called out only three parameters as being strictly required to meet minimum requirements:

- Mission profile
- Ordnance loads
- Takeoff and landing distance

Even the signature specification was not mandated as an absolute requirement but was stated as a goal, at a level that all parties believed could be achieved and that would provide acceptable mission performance.<sup>11</sup>

Two examples have been noted of tradeoffs on lower-level specifications that were made to meet top-level goals of system performance, schedule, and cost. Both the high-speed roll rate and the structure design load factor were relaxed below typical specification levels for fighter aircraft. Both modifications seem reasonable, given that the F-117 is designed for essentially a mid- to high-altitude bombing mission and is unlikely to become involved in high-performance maneuvering combat.

It seems difficult to overemphasize the value of such a strategy, if only because it is evidently so contrary to the instincts of most systems acquisition officials. Here was a program that was apparently considered important by many officials at the highest levels of government, yet

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<sup>11</sup>Later, in the production phase, the contractor did guarantee signature performance.

enormous authority was vested in the local Air Force and industry managers to make on-the-spot decisions regarding the final system and program characteristics. We will return to this issue in Section IV when we attempt to distill some central lessons from the program.

#### **Application of MilStd's and MilSpecs**

A third key management decision was that the developer was directed to comply with the *intent* of applicable military specification, standards, and regulations, but was given blanket waiver authority to adapt such applications to the special needs of the program.<sup>12</sup> For example, because this airplane was to be designated as a "fighter," it would normally be subject to a standard AF specification on the flying qualities of the vehicle. However, the mission of the F-117 was to be quite different from that of the typical fighter for which those specifications had been devised. Therefore, the appropriate officials from the SPO and the contractor jointly wrote a special flying-qualities specification that matched the needs of this particular system. Other specifications and standards were handled in a similar manner.

A related practice was that formal documentation was minimized, thus further reducing the scope of the original development activity and allowing all effort to be concentrated on achieving the desired basic system capability. One example is the Contract Data Requirements List (CDRL) in the original development contract, which contained only nine items:

- Monthly activity and cost report
- Program review material (as required)
- Program action item list (as required)
- Interim technical reports (not further defined)
- Flight test plan
- Flight manual
- Logistic support plan

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<sup>12</sup>Only one such standard was mandated, and that dealt with the handling of nuclear weapons.

- Reliability program plan
- Maintainability program plan

Note that the last six are one-time actions (although the original submission might well be revised and resubmitted over time). In a typical aircraft development program, the CDRL typically contains more than a hundred items, many of which are updated monthly or quarterly throughout the program.

### **SPO Authority**

A number of special commissions and panels have been activated during the past three or four decades with a charter to "reform" the systems acquisition process. One of the perennial recommendations of such panels has been to provide the program manager with true authority commensurate with his responsibility. Unfortunately, such recommendations have rarely been implemented, because senior administration and political personnel have been unwilling to delegate such authority in major programs. In the F-117 program, the few senior administrators who had access to the program did, in fact, delegate considerable authority to the program manager, who, in turn, delegated authority to his key staff members. The result was an exceptionally short and responsive decision process. The effectiveness of SPO management was further enhanced because the SPO had been staffed by relatively senior and capable people and because those people were able to establish a close working relationship with their counterparts in the contractor's staff.

It seems plausible that these three SPO management characteristics (delegation of authority, high-quality personnel, and a good working relationship with industry) are among the most important features of the F-117 program organization and structure. Furthermore, only the first (delegation of authority) seems closely linked to the special environment of the F-117 program. Yet, these three characteristics might also be among the most difficult to routinely replicate in future programs.

### **MAJOR PROGRAM OUTCOMES**

Having briefly described the major elements of program organization and management practices, we now will summarize some of the key outcomes of

the program. These outcomes will provide the basis for comparing the program with other, more conventional programs. Those comparisons will be presented in the next section of the report.

#### **Development Problems**

Any new airplane development program experiences some problems that are revealed when the systems, or major components, enter the test phase. In the F-117 program, several such problems required major redesign to correct, and, in most cases, the changes were incorporated after production had started. These problems are summarized below. Signature goals, the most critical aspect of the entire design, were achieved without any major redesign being required. It was, however, necessary to continually address signature issues throughout the design process, because many design decisions affected the overall signature and every such decision had to be individually examined and adjusted to ensure continuing compliance with signature goals.

**Tailpipe Assembly.** The engine tailpipe and nozzle assembly is decidedly unconventional on the F-117. The nozzle is a two-dimensional slot instead of the conventional round configuration, and the nozzle exit is forward of the trailing edge of the fuselage so that the hot gas flows across a flat "heat shield" surface before exiting into the free stream airflow. As a risk reduction measure, the nozzle and the heat shield surfaces were tested in a test cell, starting nearly a year before first flight. Several problems were discovered, including cracking caused by thermal gradients, inadequate strength of the nozzle structure, and failure of the heat shield surface material. Fixes were performed in several phases. First, addition of quilting lines to add thermal flexibility created an assembly adequate for early flight tests. Next, thermal insulation was added to the heat shield assembly, thus providing a configuration adequate for initial production. Later design improvements, including addition of a liner to the nozzle, yielded fatigue life and fail-safe capability consistent with initial design goals, were completed midway through the production run, with earlier units reconfigured during depot modification.

**Rudder Size and Structure.** On the initial test flight, it became obvious that the vertical fin area and rudder control authority were less than adequate. The fin was redesigned with a 31 percent greater area, and the new design was completed in time to be incorporated on the first production unit. Subsequently, in 1985, when about one-half of the production had been completed, a destructive flutter problem was discovered under some very special flight conditions. Corrective action required complete redesign of the fin/rudder assembly, using composite materials. That action was not completed until near the end of the aircraft production program, so most of the fleet had to be retrofitted with the new configuration.

**IRADS.** The Infrared Acquisition and Detection System was the only aspect of the avionics and weapon delivery system that was truly new (none of the basic elements of the system represented new technologies, but the integration of those elements into the particular configuration needed for the F-117 required a completely new design), and it required considerable development after the start of the flight test phase. Difficulties were encountered in maintaining physical and electrical alignment between the upper and lower turrets and in maintaining quality and stability in the picture transmitted to the cockpit. About a year of intensive design refinement and flight test was required to resolve all the problems. However, resolution of the problems occurred early enough so that the production schedule was not significantly affected.

**Wing Root Structure.** The flight loads survey conducted in the first quarter of 1982 revealed that the wing root bending movement could, under full design maneuvers, significantly exceed structure strength. The redesigned structure configuration was incorporated into the production line at the 24th unit and subsequently retrofitted into the earlier units.

**Other.** Numerous other problems were encountered during the flight test program, resulting in changes in the production configuration and service bulletins to modify units already in the field. However, none of those problems resulted in delays in the production program--changes were simply fed into the line as they became available and the earlier units retrofitted in the field or during subsequent depot overhaul. That process was, of course, considerably aided by the slow production rate. Even



though it took about four years from the start of flight test to reach the point at which the production configuration was reasonably stable, only about two dozen aircraft were produced during that time.

#### **Production and Supportability Problems**

New materials and fabrication processes unique to the LO design, combined with the fact that the configuration was far from mature when production started, led to many configuration changes during early production. One serious deficiency in quality control became apparent when some wiring was connected incorrectly, leading to the crash of the first production aircraft on its maiden flight.

One of the largest sources of configuration changes during production of the first few aircraft was the need to improve system reliability and maintainability. During the first three years of the development program, primary attention was devoted to solving the many technical problems involved in creating a flight vehicle and the associated mission avionics that satisfied the unique requirements imposed by the signature goals. When aircraft began to be delivered to the operational unit, it soon became apparent that the design suffered some serious problems of maintainability in the field. That discovery triggered an intensive program of R&M (reliability and maintainability) improvements that extended over the next several years.

The structure of that program is summarized below; the results are summarized here in terms of the change in maintenance needs. Data on maintenance and associated flight operations were available for the years 1984 to 1989. Figure 4 shows the progression of total flight line maintenance (in man hours/sortie) for the six system elements needing the most such maintenance and for all other elements together.<sup>13</sup> It is apparent that maintenance performance of the system improved substantially during the 1984 to 1988 time period. The exact reason for the reversal of

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<sup>13</sup>The appearance of the first four items in the list is not surprising. The landing gear maintenance was devoted largely to changing tires and brakes because the landing gear, which had been adapted from an existing design to reduce risk and save development cost, turned out to be undersized for the F-117.

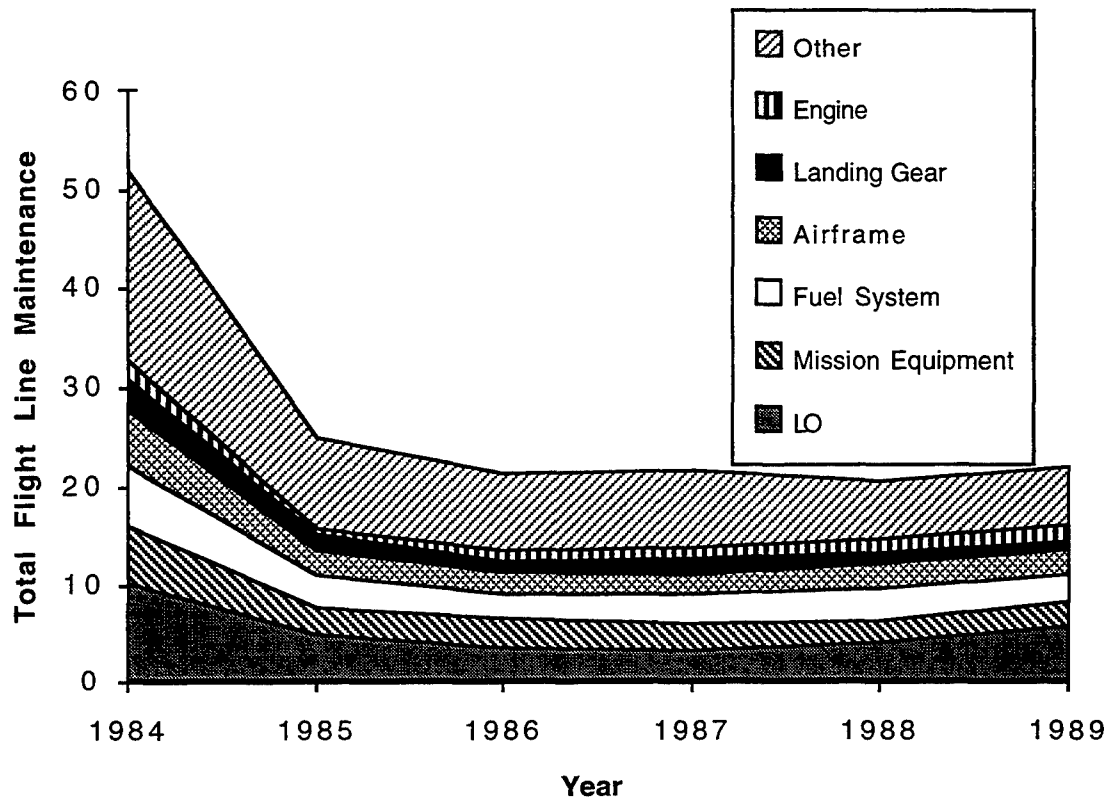


Figure 4--History of Flight Line Maintenance Activity Levels

the trend for the LO maintenance in 1988 and 1989 and for all systems in 1989 is unknown.<sup>14</sup>

In Figure 5 the total flight line maintenance data from Figure 4 is repeated, together with the accumulation of flight hours in the operational fleet. It can be seen that the periods of heavy maintenance demands occurred when the fleet was small and flight hours were accumulated at a slow rate. By the end of 1984, when flight hours began to be accumulated at an increasing rate, the overall maintenance demands of the system were much improved over the early years.

<sup>14</sup>The support organization and posture were essentially unchanged through 1988, with all operations performed at a dedicated base and with extensive maintenance support provided by the contractor. In October 1989, the formal Program Management Responsibility Transfer occurred, in which overall management responsibility was shifted from the Aeronautical Systems Center to the Sacramento Air Logistics Center. Some time later the operational unit was moved to Holloman AFB, New Mexico, but those events did not influence the maintenance trends shown here for the 1984-1989 time period.

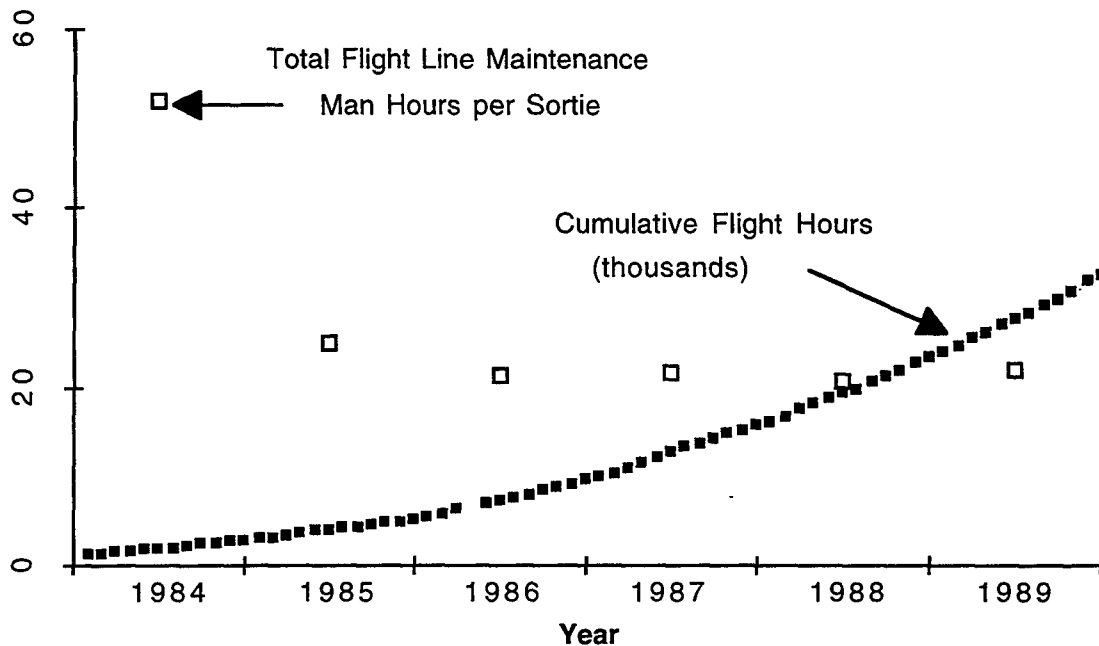


Figure 5--Trends in Total Flight Line Maintenance

#### Configuration Upgrade Program

Correcting the problems detected during the development flight test program and the R&M problems that surfaced during early field operations led to many design changes throughout the production program. In general, those changes were introduced in the production line as soon as possible, but even with the slow production rate, it was inevitable that many of the changes had to be retrofitted into aircraft already produced. The retrofits were accomplished largely through a program of five "configuration upgrade" (CU) phases, scheduled as follows:

- CU #1 (11 aircraft): Oct. 1983 to Jan. 1986
- CU #2 (8 aircraft): Aug. 1985 to Oct. 1986
- CU #3 (15 aircraft): July 1986 to May 1988
- CU #4 (25 aircraft): Jan. 1988 to Oct. 1990
- CU #5 (40 aircraft): June 1990 to Mar. 1995

It was anticipated that by the end of CU #5, all aircraft would have the same configuration.

### Flight Test Program

The fact that development work of one kind or another continued well beyond the initial development contract, which covered work up through some point in mid-1984, is apparent from the contracts summary in Table 1 and from the extensive configuration upgrade program described above. This fact is also reflected in the flight test program, as shown in Figure 6. It can be seen that the pace of flight test operations slowed very slightly after mid-1984, when the nominal EMD phase ended, but then continued at a nearly constant level throughout the remainder of the decade. The continuing test program covered a wide variety of design changes reflecting both performance improvements and R&M improvements.

### Program Costs

Development of the system occurred over several phases. The original development contract, comparable to a conventional EMD contract, was CPFF and covered development work extending from the beginning of the program to approximately the end of CY83. However, even though by end of 1983 the flight test program had accumulated more than 1,000 flights and about 15

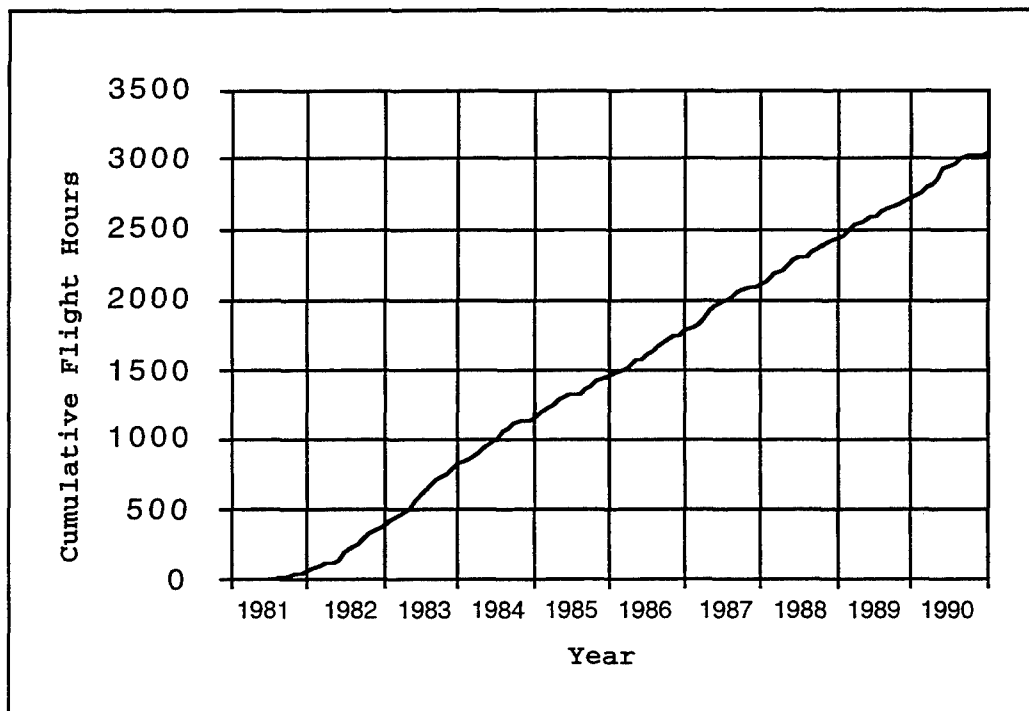


Figure 6--F-117 Cumulative Flight Test Hours

production aircraft had been delivered, the configuration was not fully mature. Therefore, a follow-on development program was initiated under a FPIF (fixed price incentive fee) contract. The sum of expenditures under those two contracts totaled about \$2 billion (FY93 dollars) through 1990, the cutoff date for this study. As the design changes stemming from both development contracts became ready for production, they were introduced into the production line and were retrofitted into units already produced. That retrofit program cost an additional \$0.5 billion through 1990.<sup>15</sup> We believe that the sum of those activities constitutes the overall program development activity, and thus we assign a total development cost of about \$2.5 billion, expressed in 1993 dollars. That sum closely approximates the total development cost shown in a 1991 Air Force briefing on the program.

It should be noted that incurring development costs after the end of the formal development phase is typical of aircraft acquisition programs. In the F-117 program, the sum of the follow-on development contract and the configuration upgrade work was a somewhat larger portion of initial development than was experienced in the F-15 and F-16 programs. This difference appears consistent with the different management policies followed in the other programs, wherein much greater emphasis was placed on completing all development work and achieving a reasonably mature and stable configuration before embarking on rate production.

Production costs for the 59 aircraft, including GFE (government furnished equipment), initial spares, and peculiar support, total about \$5.2 billion in FY93 dollars.

Before leaving the subject of program costs, it would be appropriate to address the issue of "cost growth," a common measure of program outcomes. Unfortunately, that metric cannot be defined for the F-117 program because there is no record of a systematic, inclusive estimate of total development cost made at any time near the beginning of the program.

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<sup>15</sup>Most of the cost of the Configuration Upgrade program was incorporated with the costs of the Contractor Logistic Support activity that was being performed concurrently. Unfortunately, the cost of the upgrade activity cannot be cleanly separated from that of the logistic sustainment costs. The CU costs shown here are based on estimates provided by the F-117 Program Office in 1994.

## OBSERVATIONS

One key aspect of the F-117 program that is apparent in the above description of program outcomes is that the program proceeded incrementally and, in some cases, almost experimentally. The standard policy for major acquisition programs, as described in Department of Defense directive 5000.1 and 5000.2, calls for considerable planning before each phase of activity, followed by extensive verification of successful completion of that phase before proceeding to the next phase. Of course, the risks and uncertainties in any weapons development program prevent that policy from being fully observed, but in most programs, considerable effort is devoted to minimizing the chance of problems occurring in the future. In the F-117 program, a different approach, consistent with Lockheed "Skunk Works" policies, was apparently followed, wherein somewhat greater risks were taken in the expectation that when problems did occur they would be remedied quickly.

This development management strategy is most apparent in connection with two related aspects of the F-117 program: (1) the decision to place great emphasis on achieving an early IOC (initial operational capability) through the strategy of overlapping early production with the development and test phase and (2) the apparent lack of early emphasis on reliability and maintainability (R&M) characteristics of the system.

Early commitment to production, before system capability has been demonstrated in flight test (i.e., "concurrency") has been the subject of debate over the past several decades. One major vector of policy change over that time period has been an increased emphasis on the notions that the development phase should result in a product that is fully satisfactory in nearly every dimension, and that such satisfaction should be demonstrated through extensive testing before making commitments to high rate production, so that the configuration will remain stable throughout subsequent production. That policy is believed to be appropriate in programs with large production runs, where the sum of production and operations costs are large compared with development costs. The F-117 program, however, was different from the norm in several dimensions: a very small production run was envisioned (only 20 units in the original acquisition plan), and considerable emphasis was placed on achieving an

early IOC. This different distribution of objectives and priorities inevitably yielded a program with overall outputs somewhat different from that of a typical airplane weapon system program.

Likewise, it has become standard practice during development to devote major resources toward designing and provisioning for routine operation of the weapon system. This approach is expected to be economical because it reduces the resources required to operate the system in the field and the amount of design change and retrofit required to achieve a reliable and maintainable configuration. Unfortunately, such a practice suffers from some internal inefficiencies because the early support planning is itself done on the basis of an immature configuration, resulting in some wastage. In the F-117 program it appears that a large amount of the development effort toward R&M performance was performed *after* the basic design was completed, with changes incorporated into the ongoing production line and retrofitted into the units already produced. The cost and schedule consequences of such a practice must be incorporated into any examination of overall development strategy.

### III. COMPARISON WITH OTHER PROGRAMS

This section makes some comparisons of the F-117 program with other programs that are reasonably similar in one way or another.

Comparisons between weapons acquisition programs must be examined with caution. Every acquisition program is different from every other program in many dimensions, so that it is impossible to say that a particular difference in program content or strategy led to a particular difference in program outcomes. Furthermore, some of the factors that have important effects on program outcomes might be relatively obscure and difficult to reconstruct from program records. However, such comparisons are necessary to put the results of any one program in context. For example, we observe that the F-117 had an original schedule that called for first flight 20 months after EMD start, but that the actual was 31 months. In isolation, that "schedule slip" is impossible to evaluate. We need to examine it in the context of similar schedules for other airplane development programs, adjusting as best we can for apparent differences in program content that might have affected time to first flight. By performing a number of such comparisons, we hope to develop an aggregate understanding of the effects of the special acquisition strategy and environment applied to the F-117.

#### SYSTEM PERFORMANCE

Comparison of system performance achieved in the various acquisition programs is complicated by the fact that each program has different key performance parameters, and by the fact that the performance of the key F-117 parameter signatures, is highly classified. However, some useful observations can be made.

In the vast majority of weapon system acquisition programs, the key performance goals, those central to providing the basic new mission capabilities being sought in the program, have been achieved. Cross-cutting surveys of acquisition programs have been made in which each of several key performance parameters is measured in terms of the ratio of "achieved level"/"specified level." Such ratios are nearly always very close to unity, reflecting the fact that when problems arise, cost and



schedule goals are typically sacrificed in favor of achieving performance goals.<sup>1</sup> That was true in the F-117 program; all of the major performance goals deemed critical to mission capability were achieved at levels very close to those desired.

The most significant performance problem experienced by the F-117 was in the R&M performance of the early operational items, as discussed below. That problem appears, however, to have been the direct consequence of an early management decision to not place emphasis on R&M performance, as reflected by the fact that R&M performance was treated in the most cursory manner in the original development contract. Thus, we can conclude that in terms of achieving specified levels of system performance, the F-117 program was typical of major combat aircraft acquisition programs.

#### **PROGRAM SCHEDULE**

It was noted earlier that the planned schedule was quite compressed but that the actual dates for the first flight and the first delivery schedule each slipped roughly by a year. Was that actual schedule still compressed in comparison with similar programs? The most similar program is the F-16, in which an austere prototype phase was followed directly by an EMD program and a rapid production start. A direct comparison between the F-117 and the F-16 schedules is shown in Figure 7. It can be seen that the overall pace of the actual F-117 program very closely approximated the pace of the F-16 program.

Two differences between the programs need to be addressed regarding how they affected development schedule. The first is the question of possible differences in technical difficulty. It might be argued that the F-117 was a technically more challenging program, and, until we better understand the full consequences of designing a low-signature vehicle, we must treat any such comparisons with caution. While the F-16 was not a plain vanilla airplane (it contained several major technical innovations, most notably the relaxed stability margins, together with the full-time

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<sup>1</sup>See, for example, Frederick P. Biery, "The Effectiveness of Weapon System Acquisition Reform Efforts," *Journal of Policy Analysis and Management*, Vol. 11, No. 4, 1992, and Edmund Dews et al., *Acquisition Policy Effectiveness: Department of Defense Experience in the 1970s*, Santa Monica, Calif., RAND, R-2516-DR&E, 1979.

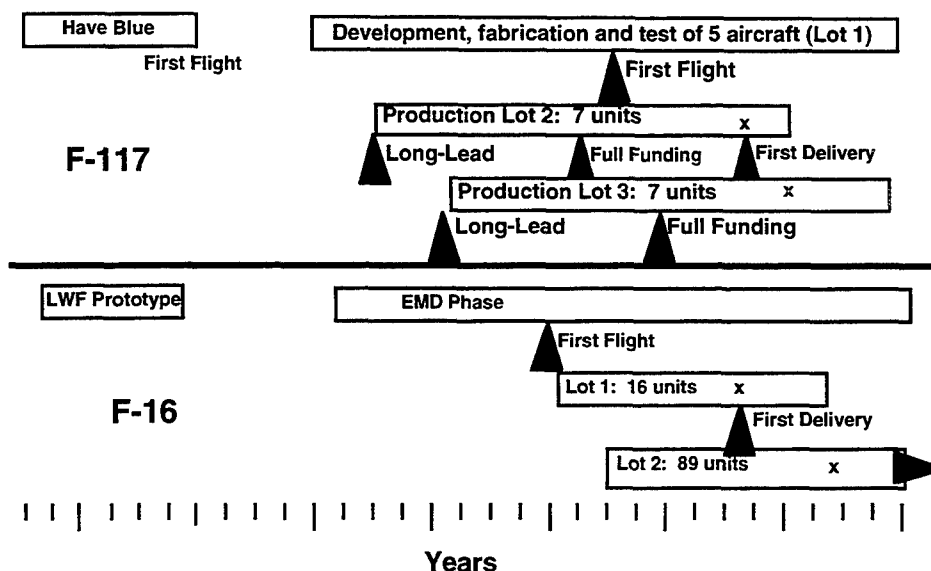


Figure 7--Schedule Comparison with F-16 Program

stability augmentation and the side-stick controller), it seems reasonable to believe that designing the first operational stealth aircraft introduced some exceptional challenges. On balance, we would have expected the F-117 development to take longer than that of the F-16.

Another major difference between the two programs was that the YF-16 was a true prototype of the F-16 flight vehicle, thereby providing a considerable start on the overall system design. Conversely, the Have Blue program was a technology demonstrator and provided almost nothing toward the detail design of the F-117. On that basis, we would expect that, measured from EMD start, the F-117 schedule would have been extended, compared with the F-16, while in fact the time to first delivery was about the same for both programs. This suggests that the F-117 program was relatively short.

A broader comparison of development phase schedule is shown in Figure 8, in which we compare the F-117 with four other aircraft, measuring each from the start of EMD. It can be seen that in time to first flight, the F-117 was the next-to-longest of the lot, but compared in terms of time to first operational delivery, only one program (the F-14) was shorter, by a couple of months. This outcome tends to confirm the fact that the F-117 was more concurrent than most programs, but, in very general terms, it was

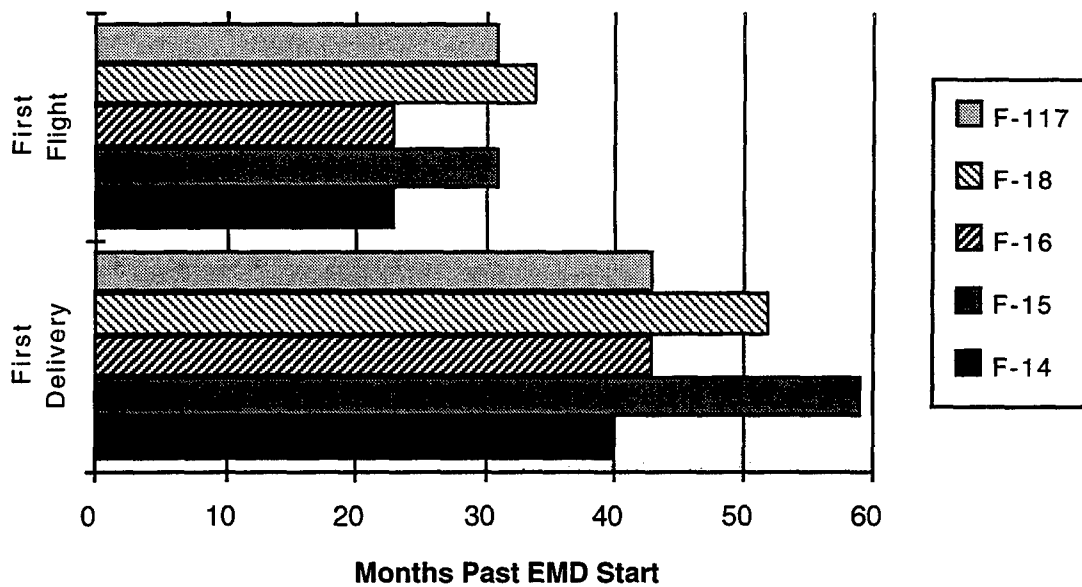


Figure 8--Comparison of Development Schedules

not substantially longer or shorter than the average of other fighter aircraft developments.

While there was clearly an effort to compress the development schedule of early first flight and first operational delivery, other aspects of the program were conducted at a pace somewhat slower than normal. The original program plan called for production of 20 units at a rate of one per month. Actual production deliveries never exceeded eight per year and were held at that rate for most of the production run, as shown in Table 2 and depicted graphically in Figure 3 above. While no evidence of a decision process is available from existing records, it seems plausible that when larger quantities were planned, toward the end of the first production lot, it was

Table 2  
F-117 Production Deliveries

Year	Quantity
1982	8
1983	8
1984	8
1985	8
1986	8
1987	7
1988	5
1989	4
1990	3

decided to stick with the low rate rather than pay for additional tooling that would be amortized over only a few remaining units. That decision seems further justified by the relatively low maturity of the early production units and the consequent frequency of configuration changes.

The stability of production as displayed in Table 2 is truly remarkable when compared with experience typical of other programs. For example, a history of production rates for the F-15 and F-16 is shown in Figure 9. Whereas the actual rates for those aircraft were much higher than those of the F-117 (approximately 50 to 100 per year for the F-15 and approximately 100 to 200 per year for the F-16), they were also much less stable. The stability of the F-117 production must surely have contributed to the cost efficiency of the program, although the extent has not been estimated.

Another indication of acquisition strategy is found in the flight test record. As shown in Figure 10, flight testing was conducted at one-third to one-fourth the pace typical of fighter aircraft development programs. A relatively small number of F-117 aircraft were dedicated to flight test,

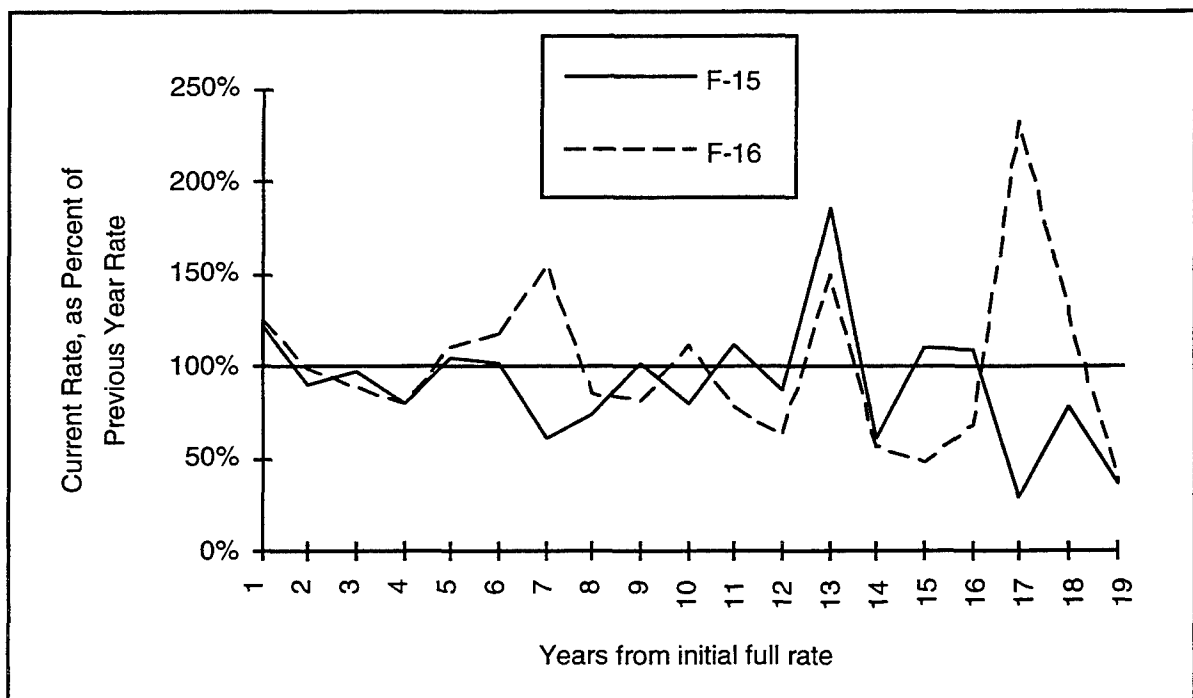


Figure 9--Year-to-Year Changes in Production Rate

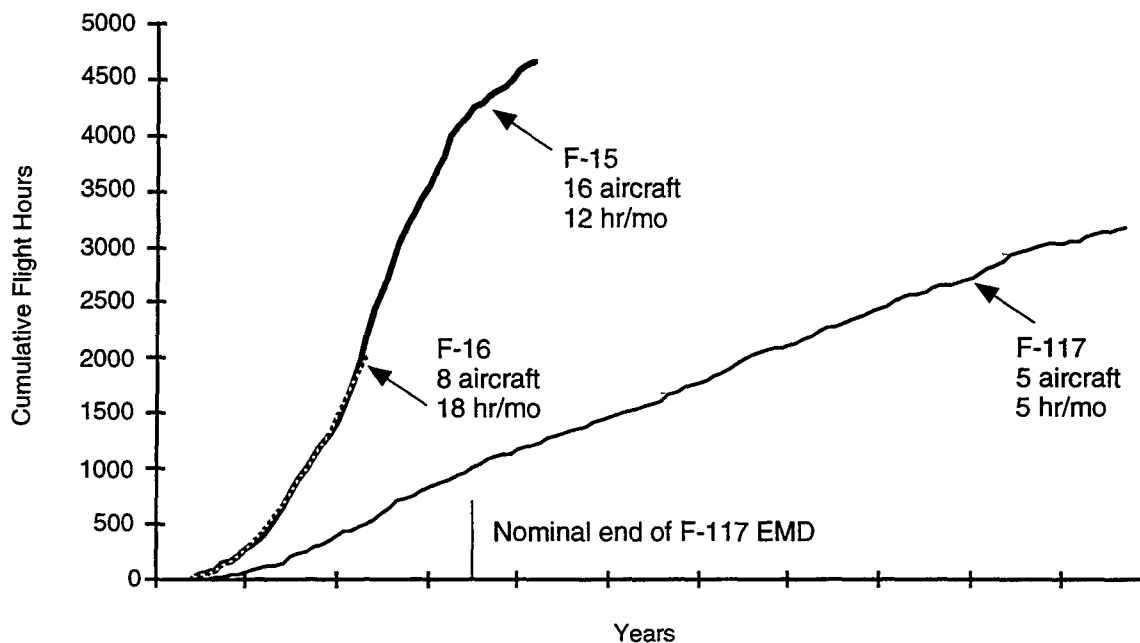


Figure 10--Flight Test Activity Rate Comparison

and those aircraft were flown at an average rate of less than half that of typical fighter aircraft during development testing. The result was that by the end of the nominal EMD phase, only about 1,000 test hours had been accumulated, compared with 3,000 to 4,000 hours in a typical program.

There are some plausible explanations for why the F-117 test program was conducted at a somewhat slower pace than conventional programs. With only 20 units expected to be produced, it would be unreasonable to allocate the typical number of 10 to 15 for flight test. The covert nature of the program led to testing being performed only at night, which probably contributed to the low utilization rate of the available aircraft; the relative high maintenance work loads must have further reduced flight activity levels. However, the overall average test activity rate of 30 to 40 hours per month (total for all five airplanes) during the height of the EMD test phase still seems remarkably low and has not been fully explained.

There are also reasons that the total amount of testing needed for the F-117 development program might be less than for typical programs. The system was designed to perform a single, narrowly defined mission, with a small number of weapons to be qualified, thus reducing the overall amount of testing needed. The lack of supersonic capability certainly eliminated

the need for testing in the supersonic regime, which can be quite lengthy. Finally, operational testing was tightly integrated with development testing, thus further limiting the overall scope of the test program.<sup>2</sup> Details of the test program have not been analyzed with sufficient depth to determine if those factors fully explain the fact that only about 1,000 hours were accumulated during EMD.

Another interesting aspect of the flight test program is that an activity rate almost equal to that of the EMD phase was sustained for at least six to seven years after the end of EMD. This is another reflection of the development and configuration upgrade activity that was conducted throughout the production phase.

It seems apparent that, except for the initial development activity, this test program proceeded at a rather low but steady level of activity. Given the considerable amount of configuration refinement and update work required after production started and the small total quantity produced, that slow pace was probably quite appropriate. However, this inevitably leads to speculation that the program might have been better off if more effort had been devoted to refinement of the design during the early production phase. Unfortunately, this program alone does not provide enough data to resolve that issue.

#### **RELIABILITY AND MAINTAINABILITY**

Perhaps the largest deviation in outcomes between typical fighter aircraft programs and the F-117 was in the level of system reliability and supportability achieved, particularly early in the program. The overall level of flight line maintenance effort is shown in Figure 5 above. To place that in perspective, we compared it with similar flight line maintenance experience from the F-16 at a comparable period in program maturity (a six-year period starting one year after delivery of the first units to the operational force).

Such a comparison is valid only to the degree that the two systems are at least roughly comparable in the characteristics that drive maintenance

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<sup>2</sup>The Air Force Operational Test and Evaluation Command did not participate in the F-117 program. Operational testing was performed by pilots from the Tactical Air Command, and such flights were interspersed with developmental test flights.

needs. Whereas there are certainly some differences (the F-16 is supersonic, is roughly half the gross weight of the F-117, but has multimission capabilities), we believe the similarities are greater than the differences:

- Both systems used engines already operating in another system.
- Both had dynamically unstable airframes, stabilized and controlled by quad-redundant fly-by-wire systems. (Note that the stabilization and control system employed in the F-117 contained many components obtained from the F-16 program and, thus, presumably benefited from some of the system maturation work already completed on the F-16.)
- The IRADS' subsystem on the F-117 is believed to be similar in complexity to the radar on the F-16. Both were new subsystems developed as part of their respective weapon systems.

Finally, the most obvious difference, the LO feature of the F-117, could be separately identified in the maintenance records and thus accounted for in the comparisons.<sup>3</sup>

The F-16 maintenance experience is compared with that of the F-117 in Figure 11. In the left-hand segment, showing F-117 experience, the open rectangles are the same data as shown earlier in Figure 5. The small solid rectangles show all maintenance man-hours except those logged against LO and, thus, should be dimensionally comparable with the F-16 data shown on the right-hand segment of the figure.

Two aspects of this comparison deserve discussion. First, the early days of the F-117 operation experienced very high maintenance workloads, whereas the F-16 started with a reasonably mature system. This difference is almost certainly a direct result of very different policies regarding R&M during the development phase of the two programs. In the F-117

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<sup>3</sup>Whereas there is a separate work unit code (WUC) in the F-117 maintenance records to account for work dealing with LO, the exact extent to which that WUC was applied is not known. For example, was work on the two-dimensional engine nozzle logged against LO or propulsion? While these uncertainties exist, we believe that most LO-related work was in fact charged against the LO WUC.

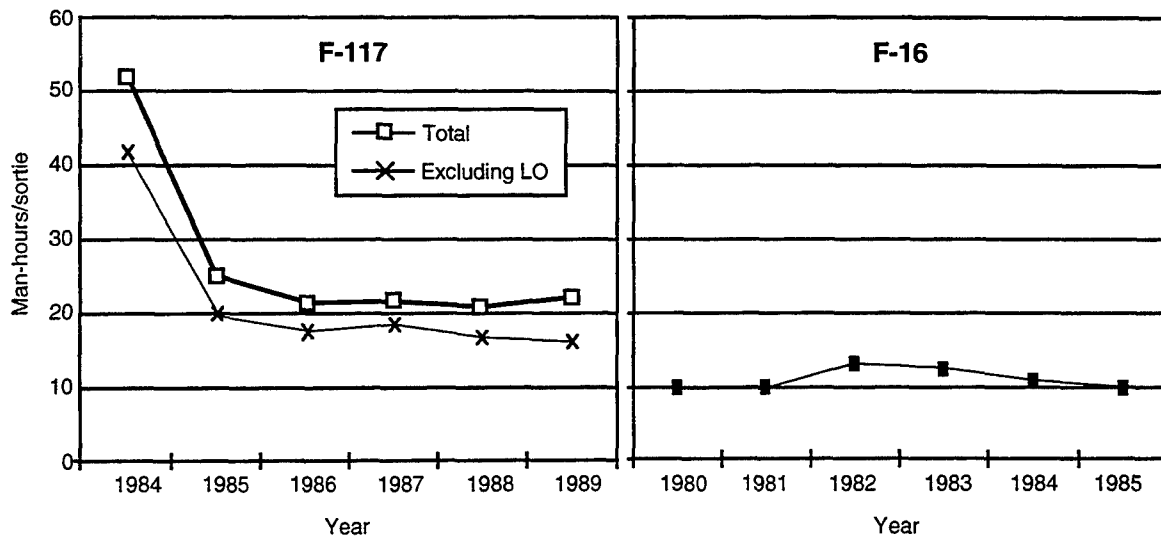


Figure 11--Comparison of Maintenance Experience

program, virtually no emphasis was placed on R&M performance until after production units began to be delivered to the operating units, whereas in the F-16 program, great emphasis was placed on achieving good R&M performance starting from the beginning of EMD. These different policies yielded different results.

A second observation is that even though the non-LO maintenance workload of the F-117 has been declining slightly over the 1985-1989 time period, it is still considerably higher than that of the F-16.<sup>4</sup> We believe this outcome is a direct consequence of continuing lack of AF emphasis on and willingness to invest in R&M performance in the F-117 program during that time period.

Further detail on the source of the difference in maintenance workload is shown in Figure 12, which compares the two systems at comparable periods of maturity, about five years after production started. Some likely causes for the individual differences are:

<sup>4</sup>The increase in maintenance workload in the F-16 that occurred in 1982 was a consequence of introducing an air-to-ground capability to the avionics package. By about 1985, the supportability had returned to pre-upgrade levels.



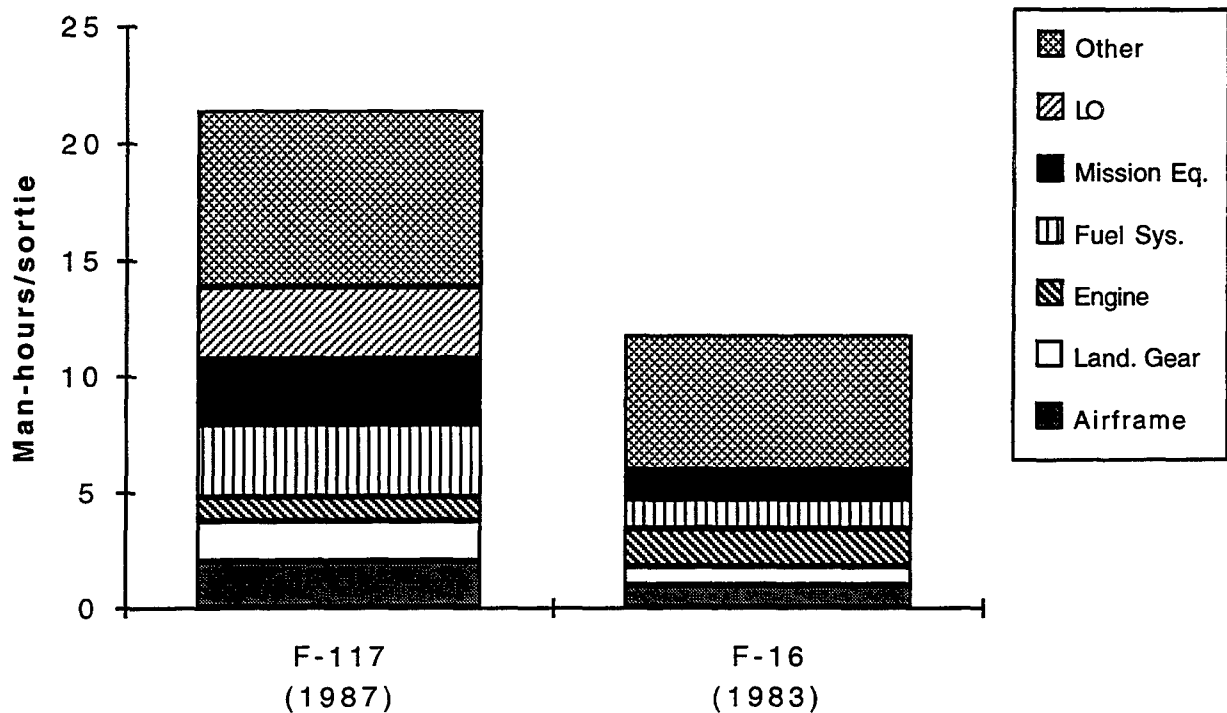


Figure 12--Sources of Maintenance Workload

- The higher airframe maintenance workload in the F-117 has not been adequately explained but is believed to be partly caused by access restrictions resulting from the LO configuration.<sup>5</sup>
- The higher landing gear maintenance workload in the F-117 is largely a consequence of having utilized an existing landing gear that turned out to be slightly undersized for the F-117. Thus, tires and brakes have required an inordinate amount of maintenance.
- The F404 engine used in the F-117 had previously been introduced in the F/A-18 program and was a reasonably mature system by the time it was installed in the F-117. Conversely, the F100 engine used in the F-16 had been adapted from the earlier F-15 and was

<sup>5</sup>Time spent opening, closing, and resealing access doors was properly charged to the LO WUC. However, placement of parts inside the airplane, as affected by the desire to limit the number and size of access doors, might have increased the resultant airframe maintenance hours.

still experiencing many problems well into the F-16 operations phase.

- The difference in fuel system maintenance is largely due to the stringent limitation on integral tank leaks imposed by the LO coating on the F-117. (Some part of this difference should probably be charged against LO maintenance, but the available data did not permit such a determination.)
- Differences in mission equipment are detailed below.

An important contributor to overall system maintenance, and especially to maintenance cost, is the mission equipment. The composition of the mission equipment package in each system is shown in Table 3. A comparison of the maintenance workload is shown in Figure 13, where the workload for each individual item, together with total, is shown for the F-117, whereas only the total is shown for the F-16. It can be seen that the IRADS is the largest single contributor to flight line maintenance, although that component improved by about one-third during the 1985-1989 time period, leading to a smaller reduction in total flight line maintenance for mission equipment in the F-117. Still, in 1989 the total flight line maintenance for mission equipment in the F-117 was more than twice that of the F-16. As in the comparison of overall system maintenance experience, it appears that the Air Force has made little improvement in the mission equipment maintenance workload beyond that achieved in the first couple of years of operations.

**Table 3**  
**Mission Equipment Components**

F-117		F-16	
WUC	Component	WUC	Component
57	Integrated Guidance	74	Fire Control
73	Bomb Nav (IRADS)	74A	Fire Control Radar Set
82	Computer & Data Display (HUD)	74B	Head Up Display
		74C	Computer, Fire Control Set
		74D	Inertial Navigation Set
		74K	Multifunction Display Set
		74L	Radar Altimeter

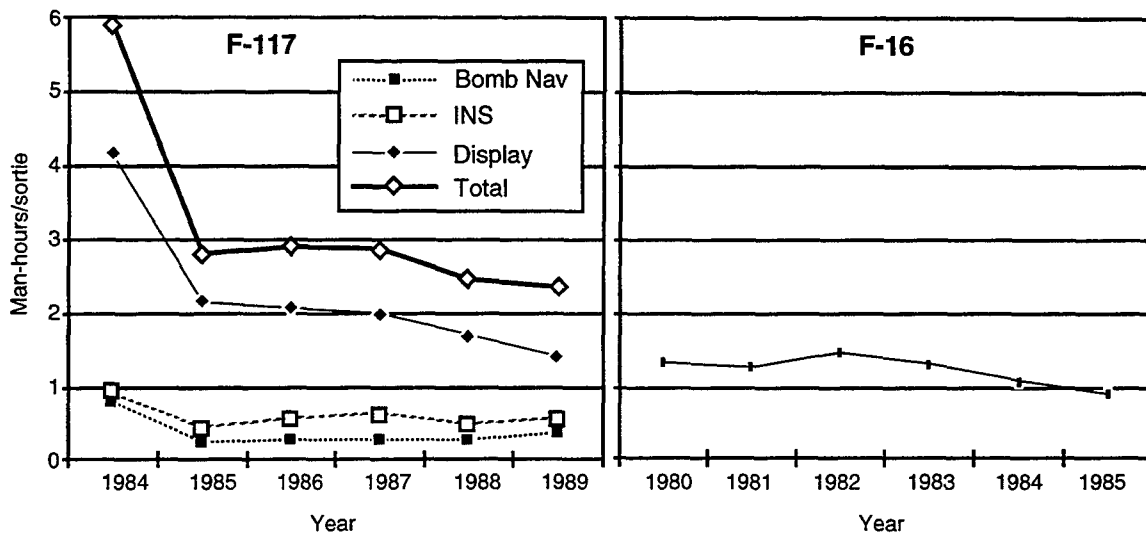


Figure 13--Comparison of Mission Equipment Maintenance Workload

#### R&M Maturation

A secondary objective of the study was to examine how R&M maturation of complex avionics systems was performed, despite the very slow accumulation of operational flight hours. Unfortunately, we found no evidence that any such program was attempted (beyond the initial major improvement in 1984), and so this research objective could not be fulfilled.

#### COST COMPARISONS

A brief outline of the actual costs incurred in the F-117 acquisition program was shown in the previous section. Here, we wish to explore how those costs compare with other aircraft. This issue is of major importance when addressing the effectiveness and efficiency of "streamlined" acquisition strategies. Do such strategies, employing elements such as CPFF contracts and minimal oversight, lead to different overall program costs?

#### Acquisition Costs

One of the first questions to be addressed is the degree to which the special LO characteristics of the airplane, together with the unorthodox

program management structure, affected the development and production costs. In an attempt to examine that question, we used two approaches.

The first was to employ standard cost analysis methods to estimate the costs of the program. These costs were then compared with the actual costs. Results are shown in Table 4. The F/A-18A was determined to be the best basis for comparison; thus, actual F/A-18A costs were adjusted in various ways to match the size and other characteristics of the F-117. One such adjustment was to include the cost of the first five EMD aircraft in the EMD category (to match the F-117 program structure) and to show as "production" the cost of the next actual 59 aircraft. This accounts for the different number of aircraft in the F/A-18's EMD program. Additional R&D costs incurred in the years immediately after EMD completion were included in the F-117 development costs, along with the cost of modifying and retrofitting the aircraft already produced.

Of course, there are many differences between the F-117 and the F/A-18, in addition to those noted in Table 4: the F-117 is a subsonic, LO aircraft whereas the F/A-18 is a supersonic, non-LO aircraft, and so on.

**Table 4**  
**F-117 Actual Costs Compared with Estimated Costs**  
**(FY93 dollars, millions)**

	Actuals	Estimates
Total	\$7,700	\$7,900
EMD	2,500	3,000
Nonrecurring		1,390
Structures		790
Systems		440
Engines		140
Avionics		240
Production	5,200	4,900
Structures		2,400
Systems		1,340
Engines		420
Avionics		740
EMD cost includes the cost of five flight test aircraft.		
Production cost covers costs of the next 59 aircraft produced.		

The effects of such differences are outlined in Table 5. Despite these differences, and given the relatively poor precision of such parametric estimation procedures, the fact that the estimated total acquisition is within 3 percent of the apparent actual acquisition costs is gratifying. The results suggest that the actual F-117 development phase was somewhat less expensive than that predicted by the estimation process, whereas the slightly higher production cost is consistent with the expectation that very low production rates tend to increase costs. This overall comparison seems to support a general observation that the costs of the F-117 acquisition were about the same as one would have expected from the cost of a conventional airplane developed in a conventional manner.

Another approach to understanding the F-117 costs is to simply compare them with the acquisition costs of similar aircraft. One such comparison is shown in Figure 14. Here, two cost components are shown for each system: the development cost, including the cost of producing the first five test aircraft; and the production cost of the next 59 aircraft.<sup>6</sup> All costs are adjusted for inflation and shown normalized to the size of the F-117. Adjustments for engine development differences and post-EMD development have also been made.

**Table 5**  
**Effects of Uncontrolled Variables on F-117 Relative Cost**

Factor	Relative Effect on F-117 Cost	
	Development	Production
Stealth	Increase	Increase
Security	Increase	Increase
Use of existing components	Reduce	Reduce
Oversight/documentation	Reduce	Reduce
Low production rate	Reduce	Increase
Flight envelope	Reduce	—
Design maturation	Reduce	—

<sup>6</sup>The other programs are adjusted by moving the cost of fabricating the sixth and subsequent EMD aircraft from the development cost category to the production cost category. This adjustment takes care of the fact that different programs employ different numbers of aircraft in their development.

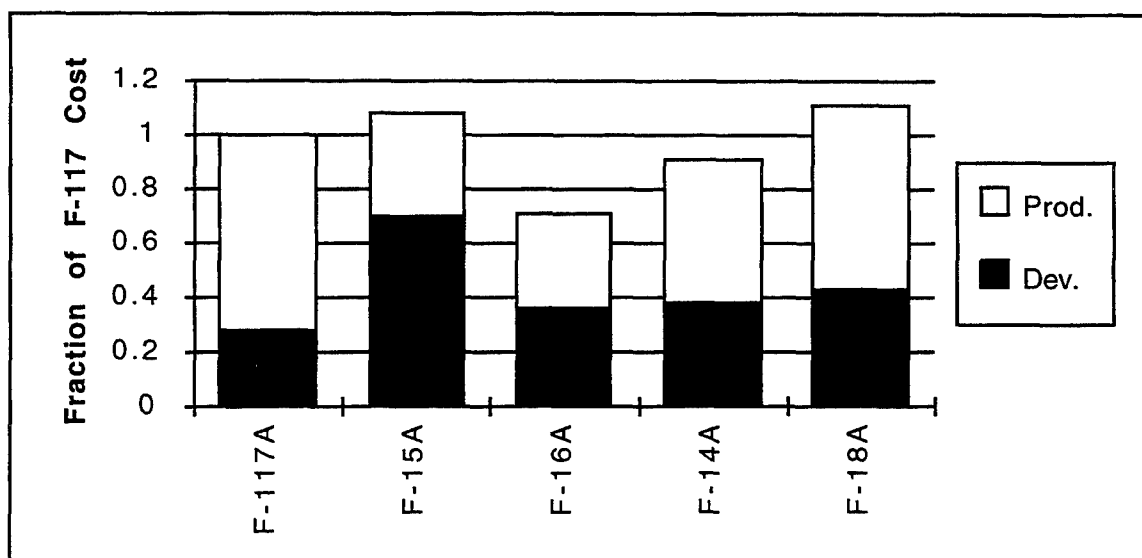


Figure 14--Acquisition Cost Comparison; Costs Adjusted for Aircraft Size, Engine Development Cost, and Post-EMD Development Costs

Three procedural aspects deserve discussion. First, the process of adjusting for the differences in the number of development aircraft in each program introduces some inconsistencies in the distribution of costs between the development and production programs. Navy procedures result in a somewhat steeper learning curve compared with Air Force procedures, so that the development and early production aircraft appear to be relatively more expensive for the F-14 and the F/A-18 than for the F-15 and the F-16. Consequently, the comparison of either the development or production program cost of the F-117 to the Naval aircraft might be considered more legitimate than comparison with the Air Force aircraft because of the capital/labor decisions made in the F-117 program. This program's very low total production quantity (20 units planned) suggests a more labor-intensive production plan. This deduction would be consistent with higher unit costs for early aircraft and a steeper learning curve for the low-quantity program.

Second, no adjustment is made to account for the fact that the other aircraft were all produced at a much higher rate than the F-117. Preparation for that higher rate would presumably increase the development investment for those other aircraft but would tend to decrease the production costs because the initial 59 would support a smaller overhead

burden. It is believed that this factor is largely responsible for the relatively low overall cost of the F-16 program, in which high production rates were achieved very quickly and overhead costs were further diluted by coproduction of units for European nations.

Third, the costs of the comparison aircraft were adjusted to account for differences in vehicle size and weight, total installed thrust of engine(s), and level of avionics equipment. Costs were also adjusted to account for the fact that different amounts of engine development costs were charged to the different systems included in the comparison. We further adjusted the costs by adding to each program the development costs incurred during the first six years after EMD completion.<sup>7</sup> The result suggests that, with the exception of the remarkably low production cost of the F-16, the acquisition cost of the F-117 is "about the same" as the acquisition costs of other fighter aircraft.

While the comparison displayed in Figure 14 includes adjustments for all the cost factors for which we have some reasonably good adjustment methods, several factors are left that differ across the set of aircraft used in the comparison. Seven such factors, and the effect that each might logically have on the relative cost of the F-117, are shown in Table 5. The incorporation of stealth and the special security rules imposed on the program certainly caused a relative increase in both development and production costs. Conversely, the use of existing components and the relaxed oversight and documentation requirements should have reduced the cost of both development and production. The effect of the relatively low production rate should have led to lower investment in tooling and facilities during development. These lower investments result in more labor-intensive and less automated production processes, which precipitate higher unit production costs. In addition, when production rate is very low, underutilization of facilities and specially qualified shop staff

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<sup>7</sup>An inspection of development spending history for different aircraft programs shows that post-EMD development spending on the original model was clustered in the first five or six years after EMD completion. After that point, development funding tended to increase sharply as work started on the subsequent model (e.g., the F-15 C/D models, versus the original F-15 A/B models).

occurs,<sup>8</sup> thus increasing unit cost. Whether the rate of eight aircraft per year was low enough to cause such inefficiencies is unknown. The remaining two factors shown should have reduced development cost, but their effect on production costs is uncertain.

No satisfactory rules or procedures are available for quantitatively defining the net effect of these remaining differences. However, it is the judgment of the authors that the net effect is likely to cause a relative increase in F-117 cost, rather than a decrease. To the extent that belief is justified, we can then very tentatively conclude that the special management practices employed in the F-117 program might have led to some cost efficiencies and that they almost certainly did not lead to any large cost penalties. Thus, the results of this cost comparison approach are consistent with those of the "cost estimation" approach described above.

#### **Operating and Support Costs**

Having observed that maintenance requirements were somewhat higher than on other contemporary fighter aircraft, we wanted to know if that was reflected in O&S (operation and support) costs. Historical data across multiple weapon systems were not readily available, but one source was found that provided comparative data for the 1993/1994 time period.<sup>9</sup> Data from that report for five fighter-class aircraft are shown in Figure 15.

It is immediately apparent that the operating cost of the F-117 is substantially greater than that of other contemporary fighter-class aircraft and that three components of cost are the biggest contributors to the difference: personnel, depot repair, and fixed costs. Personnel costs are remarkably similar among the other four systems shown here, with the F-117 being about 40 percent greater than the average of the others. We believe this difference is largely attributable to the greater maintenance staff effort required to support the F-117.

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<sup>8</sup>The Lockheed Skunkworks operation was able to minimize these effects because of the division's ability to "borrow" key personnel and facilities from other corporate divisions during the development and production of the F-117.

<sup>9</sup>*Weapon System Cost Reduction*, HQ USAF/CC brochure, May 1994.



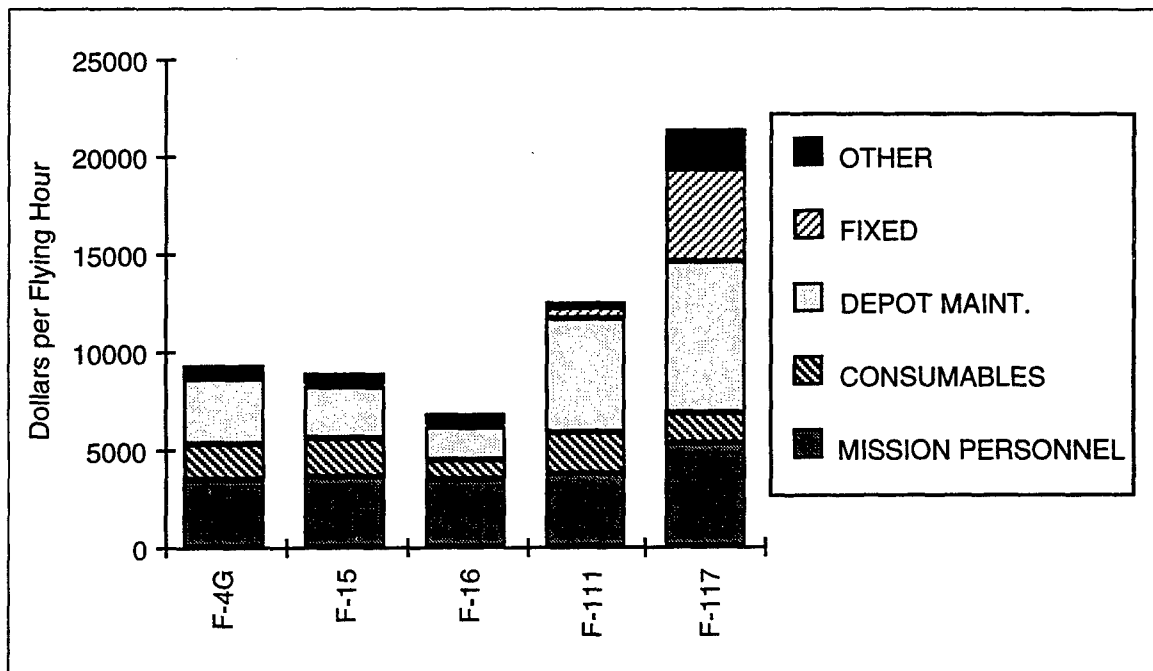


Figure 15--Total Operating Cost in FY94

The F-117 is unique among these airplane systems in that a significant part of depot-level support is performed by the contractor. Thus, the calculation of depot repair costs shown here for the F-117 might not be perfectly consistent with those for the other systems. Furthermore, we have no way of separating LO-related costs from those of other costs at depot level. Therefore, we have no basis for estimating the effect of system R&M performance on depot level costs, but it seems likely that the R&M characteristics of the F-117 contribute at least part of the higher depot level costs, whereas LO features probably contribute the remainder of the difference.

The other major element of F-117 operating cost is the "fixed" category, consisting of sustaining engineering and software maintenance. All other cost elements are generally proportional to the fleet size and flying activity rate, but the fixed costs are relatively insensitive to those factors. Thus, the relatively small fleet size of the F-117 leads to the fixed cost being amortized across only a relatively few flying hours, amplifying the apparent size of this cost element. When the fixed-cost element of each program is normalized to a constant fleet size, we find

that the fixed-cost component of the F-117 is similar to that of the F-16, but about twice the average of the other four aircraft systems shown on the chart.

We are thus left with the conclusion that system maintenance contributes a major portion of the difference in total operating cost shown in Figure 15, with the exact portion impossible to estimate on the basis of available information.

#### IV. SUMMARY OBSERVATIONS AND CONCLUSIONS

Our major objective in performing the analysis reported in the previous sections was threefold: (1) to determine the main elements of acquisition strategy and process in the F-117 program; (2) to determine whether program outcomes were generally favorable or unfavorable relative to conventional acquisitions and to what extent those outcomes could be linked with acquisition strategy and process; and (3) to suggest how any acquisition strategies that seem to have a favorable effect on program outcomes might be more broadly applied. In this final section we will present our observations and conclusions on each of those questions.

##### ACQUISITION STRATEGY AND PROCESS

A central aspect of the F-117 acquisition was the exceptional degree of flexibility and responsiveness in decisionmaking. This trait was aided by several important features of the program structure:

- The CPFF contract used to fund the development phase provided an overall institutional framework wherein decisions could be implemented with a minimum of fuss and delay.
- The system specifications were expressed in the form of contract goals rather than hard requirements. This framework allowed the managers considerable flexibility; they could tailor design decisions in response to overall program goals instead of having to satisfy a large number of predetermined measures of contract performance.
- Effort was narrowly focused on achieving a true LO airplane and doing it quickly and in great secrecy.
- The Air Force managers and the industry managers shared an unusual degree of professional respect and rapport, which led to good communications and prompt resolution of issues.
- The Air Force Program Office staff was exceptionally small; only about one-tenth that of a typical combat aircraft program office. In part, this was made possible because of the "silver bullet"

program concept. A very small production run was anticipated, followed by operation in a special environment, thus substantially reducing the emphasis on extensive design maturation before the start of production. Every member of the staff was also empowered to a remarkable degree. Staff members were handpicked for their particular kind and level of expertise, and they were encouraged to act independently and to minimize administrative coordination unless they deemed it necessary. Finally, the special circumstances surrounding the program made it unnecessary for the AF program office to spend very much time reporting to higher HQ.

#### **External Environment**

The SPO procedures and performance outlined above could not have been achieved without some special enabling features of the environment in which they operated:

- The program was covert, thereby strictly limiting the number of people who might have an opportunity to meddle in program management and shielding the program from the critical scrutiny of public and media who do not understand the dynamics of complicated, high-technology development programs.
- The program received strong institutional support from the small community of senior officials who had management responsibility, and that support did not waver throughout the development and procurement phases. Furthermore, those senior officials had the authority to issue enabling directives as necessary. Thus, the management communications from the SPO to higher HQ was fast and efficient.
- No major changes were made in performance requirements or other program specifications after start of development, except for increasing the total quantity produced. The consequent degree of program stability relieved the contractor and AF program office staffs from the burden of system redesign and program restructuring that is typical in conventional programs.

- The F-117 was never in the main stream of Air Force combat aircraft programs. Only 20 operational aircraft were expected to be produced, and those would operate in ways not even envisioned by standard Air Force doctrine. Whereas the program sponsors certainly believed the F-117 would provide a new and important combat capability, the system was never expected to play a major role in AF force structure. We believe this situation provided a special environment wherein the managers at all levels did not feel required to perform the full range of risk-avoidance practices that are part of major systems acquisition policy. This factor alone provided opportunities for major streamlining of both management and program structure.

We do not mean to imply that managers performed imprudently. Major risks were recognized and appropriate measures taken to reduce those risks to levels deemed acceptable *for that program*. The most obvious example was the Have Blue program in which the basic LO strategy was demonstrated well before an operational weapon system development was started. Other examples of prudent risk reduction appear throughout the development phase. But conspicuously missing from the F-117 program was the large engineering and management overhead typically devoted to planning and analysis to minimize the chance of unexpected problems arising. Instead, a more "cut-and-try" approach was adopted, together with a management process that enabled rapid and effective recovery from problems that did arise. This approach seems to have worked reasonably well in the special circumstances of the F-117 program.

#### **Program Outcomes and Linkages with Acquisition Process**

Those acquisition procedures and the special environment in which they were employed are interesting only to the extent that they affected the program outcomes. It would be desirable to measure program outcomes in terms of value received in return for resources consumed. Unfortunately, value is hard to measure in military systems, so the usual stratagem is to evaluate outcomes in terms of how closely they conform to original expectations (cost growth, schedule slip, and so on.). That approach is

not satisfactory in the F-117 program, because we could find no valid "original expectation" for program costs and the original plan for development schedule was extremely ambitious and well outside the band of historical experience. Therefore, in this analysis the outcomes are judged through comparison with other, roughly similar and contemporary fighter aircraft programs.

**Program Outcomes.** In most regards the F-117 program outcomes appear representative of contemporary weapons acquisition programs. Key performance goals were achieved, as they are in most military aircraft development programs. Actual development schedule was comparable with that of contemporary programs. The total acquisition cost of the F-117 program was roughly comparable with the costs of contemporary fighter aircraft systems, after adjusting for production quantity and other major program and design differences. Those comparisons suggest, but do not prove conclusively, that perhaps F-117 costs were somewhat below what would have been expected from the development of a conventional aircraft using conventional acquisition practices.

Two special aspects of program outcomes deserve special attention. One is that while conforming to typical cost and schedule outcomes, the F-117 developers introduced a novel configuration that incorporated a radical new technology, LO, and an entirely new operational concept through successful combination of LO and precision weapon delivery. To the extent that the design problems encountered and solved during the F-117 program were more than typically difficult and complex, then the outcomes that at first appeared to be typical begin to appear atypical and exemplary.

This impression of atypical outcomes is further strengthened by closer examination of program costs. If there is a major cost penalty associated with LO performance, as believed by many and as suggested by fragmentary studies, and an additional cost penalty (10 percent has been suggested) resulting from exceptional security restrictions, then these considerations further strengthen the conclusion that the F-117 costs were somewhat less than might have been expected in a conventionally organized and managed program.

The second special aspect of program outcomes is that R&M problems appear to have substantially delayed true IOC. The relatively low level of

attention paid to R&M considerations during F-117 development tends to counterbalance the additional resources that are presumed to have been needed to achieve LO performance. Not enough information is available to make a judgment about the relative effect of these two factors on resource consumption, except to note that one would tend to offset the other.

**Effects of Acquisition Strategy.** Can we link any elements of the acquisition strategy to any aspects of the program outcomes? To the degree that the outcomes were "typical" whereas the acquisition strategy was distinctly "nontypical," then by definition the strategy must have had no special effect on the outcomes. But as we noted above, there are strong suggestions that the outcomes were somewhat better than might have been expected, based on historical evidence, had typical management practices been employed. To the extent that this deduction is true, then the special streamlined procedures must have made some contribution to overall program success.

Specific linkages between a particular element of management practice or acquisition strategy and a particular measure of program outcome generally cannot be made because too many elements of this program were unusual, and we cannot confidently separate their individual effects. However, the overall set of "streamlined" management procedures, wherein great emphasis was placed on product but much less on the niceties of standard process, seems consistent with the impressions of better-than-average outcomes.

In only one aspect of the program does it seem possible to specifically link some element of acquisition strategy or management with a specific program outcome. The minimal attention given to operations and sustainment factors early in the program clearly led to very poor R&M performance in the early aircraft. The worst problems were corrected by redesigns and retrofits early in the production program, and the results might have been adequate had the production run stopped at 20 units. When the decision was made to produce 59 units and later to operate the aircraft in a standard USAF support environment, additional R&M improvements almost certainly should have been made, but were not. Had such improvements been made, including a maturation program focused on the most troublesome and high-value components, some additional program investment, including more

program office staff, would have been required to implement these improvements.

**CAN F-117 MANAGEMENT STRATEGIES BE MORE WIDELY APPLIED?**

From the complex interplay of cause and effect that we have observed in this program, we can make one unambiguous conclusion: if a special environment similar to that which existed in the F-117 program can be achieved, then it is clearly possible to successfully manage a major acquisition program with staffs very much smaller than are common in "typical" acquisition programs. But a substantial set of "special circumstances" are a necessary and enabling condition. At least four elements of such an environment seem critically important:

- Strong and sustained support for the program, thus enabling a high degree of program stability, together with freedom from having to constantly defend and protect the program from critics;
- A willingness to delegate decision authority to relatively low levels of the organization to enable response to problems and issues that is both rapid and based on a thorough understanding of the program;
- Some tolerance for risks and uncertainty about detailed program outcomes; and
- Ability to staff the program office with people fully qualified to assume the responsibilities vested in them.

It seems unlikely that such an environment can be created for a wide range of acquisition programs, simply because of the constraints built in to our form of government. Furthermore, we would not advocate that the F-117 acquisition strategy and management practices be applied in every new program. Each program is different, and we strongly believe that the acquisition strategy and management approach needs to be tailored to the circumstances of each individual program. One size does not fit all. However, at least two elements of management strategy almost certainly could and should be more widely applied.



One element of F-117 strategy that could be more widely applied is to delegate more decision authority to the program office level, with a concomitant reduction in detailed, documented oversight by higher HQ. The F-117 program is a textbook example of an effective distribution of functions: the higher HQ provides broad program guidance and an enabling environment and delegates detail design decision authority to the program office.

A second, and related, strategy is to contractually "require" only a very few key performance requirements and to establish reasonable goals for the remainder. Additionally, a clear set of program priorities must be established to guide designers and managers when making design decisions. If those opportunities for design flexibility and priority guidance can be combined with a tight management decision process, then important improvements in overall development efficiency should be obtained. It should be noted that this basic approach is a centerpiece in at least some of the Advanced Concept Technology Demonstration programs now being initiated.<sup>1</sup>

A common thread running through these initiatives is that to implement them requires a substantial level of mutual trust and professional respect among the various government agencies involved in the acquisition and between the government staff and the contractor(s). A lack of such trust and respect is the basis for many of the process controls that were specifically waived in the F-117 program. It is promising to note that many of the acquisition reform initiatives now being sponsored by senior DoD and service acquisition officials appear to encourage trust, respect, and even the use of common sense among acquisition managers, but conclusive results of such reforms have not yet been widely observed.

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<sup>1</sup>See Advanced Concept Technology Demonstrations, Master Plan, April 1995, Office of the Under Secretary of Defense (Acquisition and Technology).

## APPENDIX A

### ANALYSIS OF F-117 MAINTENANCE RECORDS

During the analysis of flight line maintenance records for the F-117, and the comparison of those data with comparable data from the F-16 program, the relatively high level of maintenance man-hours per sortie required for most elements of the F-117 raised the question of whether the records were accurately reflecting real maintenance needs. One hypothesis was that the maintenance organization was over-staffed during the early days of the operational phase to provide training to flight line maintenance personnel assigned to support this new system.

To test this hypothesis, we examined two related measures of maintenance demand. First, we examined the frequency of maintenance actions, on the assumption that the number of maintenance jobs should not be affected by staff availability. Results are shown in Figure A.1. The results show the same pattern as the display of maintenance man-hours per sortie reported in the main body of the report.

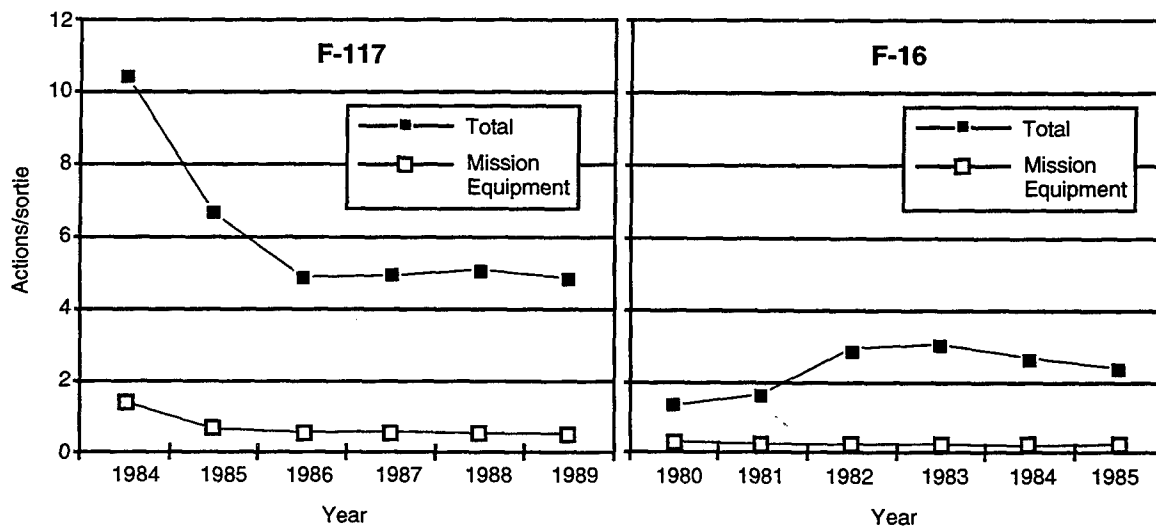


Figure A.1--Comparison of Maintenance Actions per Sortie

To further understand the comparisons, we examined the average maintenance hours per maintenance action. Results are shown in Figure A.2. It can be seen that on average, maintenance man-hours per action are slightly larger on the F-16 than on the F-117. Therefore, we cannot explain the higher level of overall maintenance man-hours consumed on the F-117 by presuming excess levels of manning assigned to training.

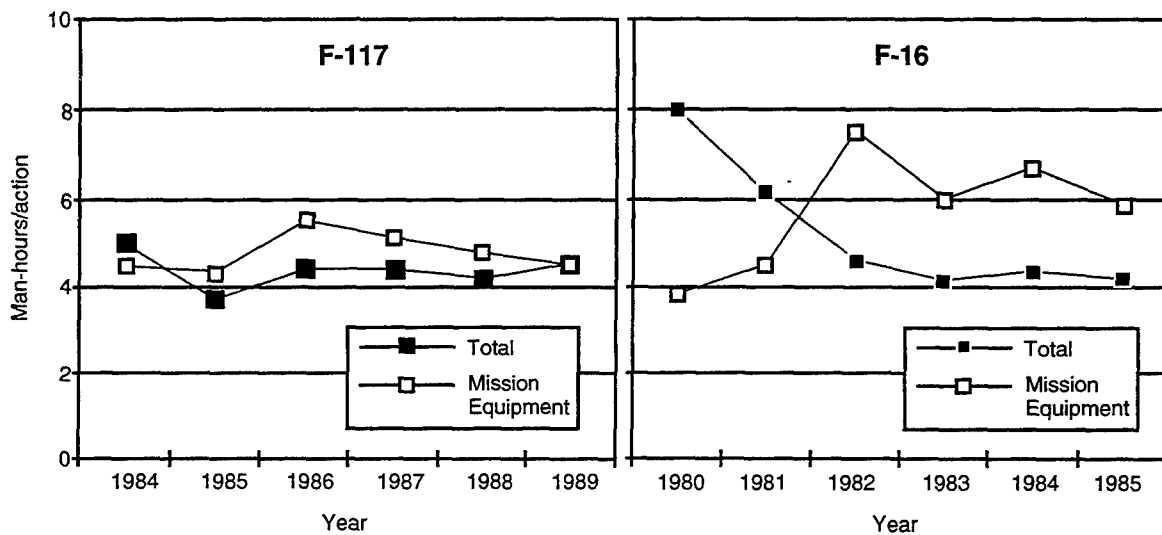


Figure A.2--Comparison of Maintenance Man-hours per Maintenance Action